JUL 2 2 1929

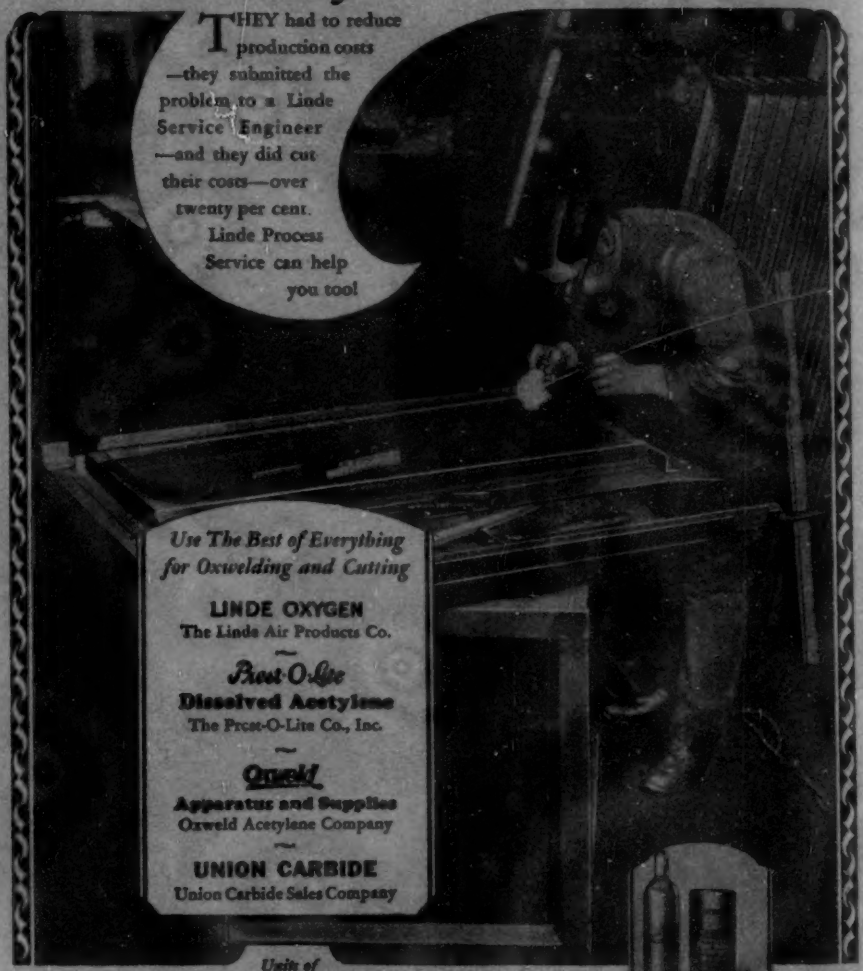
VOLUME 8 NUMBER 6

Journal
of the
American Welding Society

June, 1929

Published Monthly
by the
AMERICAN WELDING SOCIETY
33 West Thirty-ninth Street
New York

—and they did cut their costs!


THEY had to reduce production costs —they submitted the problem to a Linde Service Engineer —and they did cut their costs—over twenty per cent. Linde Process Service can help you too!
Use The Best of Everything for Oxwelding and Cutting
LINDE OXYGEN
The Linde Air Products Co.
Prest-O-Lite
Dissolved Acetylene
The Prest-O-Lite Co., Inc.
Oxweld
Apparatus and Supplies
Oxweld Acetylene Company
UNION CARBIDE
Union Carbide Sales Company

Units of

UNION CARBIDE AND CARBON CORPORATION

General Offices UCC *Sales Offices*

30 East 42nd Street, New York, N. Y. In principal cities of the country

64 Linde Plants—45 Prest-O-Lite Plants 154 Oxygen Warehouse Stocks—138 Acetylene Warehouse Stocks—38 Apparatus Warehouse Stocks 255 Carbide Warehouse Stocks

JOURNAL

of the

AMERICAN WELDING SOCIETY

Copyright 1929, by the American Welding Society,
33 West Thirty-ninth Street, New York

Subscription $10.00 per year to United States. $11.00 to Canada. Libraries $5.00.
Back numbers, per copy: Members, $0.50; Non members, $1.00.

The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication, provided proper credit is given.

Volume 8 **JUNE, 1929** **Number 6**

TABLE OF CONTENTS

Society and Related Activities

Page

Annual Meeting 3
New Officers 3
Annual Dinner 4
Bureau Officers 5
President's Annual Report 5
Samuel Wylie Miller Medal 8
Welding—A New Design Medium 9
Welding Information 9
Arc Welding Influences Machine Design 10
Welding Conference at Smith College 11

Technical Papers, Items and Reports

Autogenous Welding Serves the Chemical and Process Industries, by T. McLean Jasper 12
How to Organize and Operate an Industrial Welding School, by J. C. Lincoln 17
How to Organize and Operate an Industrial Welding School, by N. E. Wagner 20
Organization and Management of Industrial Welding School, by F. E. Sellman 23
Organizing and Operating an Industrial Welding School, by C. E. Conway .. 28
Welding in Aircraft, by H. A. Backus 32
High Pressure Distribution of Manufactured Gas by the Aid of Welded Pipe Lines, by C. M. Hendry 46
All Welded Barge, by E. H. Ewertz 55
Thermit Welding of Rail Joints for Main Line Tracks of Steam Railroads, by J. H. Deppeler 58
Code for Fusion Welding and Gas Cutting in Building Construction—Report of Committee 69
Organizing and Operating an Industrial Welding School, by R. B. Lincoln .. 77
Current Welding Literature 82

SECTION OFFICERS AND HEADQUARTERS

PHILADELPHIA

Engineers' Club, 1317 Spruce St., Philadelphia, Pa.

Chairman—J. J. Dunne, Paschall Oxygen Co., 23rd St. and Island Ave., Philadelphia.
Secretary—H. E. Hopkins, 709 W. Huntington St., Philadelphia, Pa.

CHICAGO

608 So. Dearborn St., Chicago

Chairman—H. E. Gannett, Chicago, Burlington & Quincy R. R.
Secretary—M. S. Hendricks, The Acetylene Journal, Chicago.

PITTSBURGH

311 Ross Street

Chairman—W. W. Reddie, Westinghouse Elec. & Mfg. Co.
Secretary—G. H. Danforth, Jones & Laughlin Steel Corp.

NEW YORK

33 West Thirty-ninth Street, New York

Chairman—A. F. Keogh, Sound Welding Company.
Secretary—C. Kandel, Craftsweld Equipment Corp.

NORTHERN NEW YORK

General Electric Co., Schenectady, N. Y.

Chairman—J. D. Wright, General Electric Co. Building 105, Schenectady, N. Y
Secretary—F. M. Jefts, General Electric Co.

CLEVELAND

Engineer's Room, Carnegie Hall, Cleveland

Chairman—R. K. Randall, Cleveland Welding School, 2094 East 19th St., Cleveland.
Secretary—C. J. Bornemann, Euclid Crane & Hoist Co., Euclid, Ohio.

SAN FRANCISCO

Park Ave. & Halleck, Emeryville, Cal.

Chairman—R. H. Atkinson, Page Steel & Wire Co., San Francisco
Secretary—H. W. Saunders, Air Reduction Sales Co.

LOS ANGELES

Higgins Building, Los Angeles

Chairman—A. E. DeBurn, Pacific Pipe & Supply Co.
Secretary—N. R. Shade, General Petroleum Corp.

BOSTON

Affiliated Technical Societies of Boston, 715 Tremont Temple, Boston

Chairman—C. W. Babcock, 10 High Street, Boston.
Secretary—H. N. Ewerts, 142 Berkeley St., Boston.

WESTERN NEW YORK

500 Morgan Bldg., Buffalo, N. Y.

Acting Chairman—F. L. Rodgers, Linde Air Products Co.
Secretary—G. W. Swan, J. A. Roebling's Sons Company

DETROIT

5757 Trumbull Ave., Detroit

Chairman—R. G. Richards, Barnes Wire Fence Co., Detroit.
Secretary—Albert La Poe, Westinghouse Elec. & Mfg. Co., 5757 Trumbull Ave, Detroit.

PORTLAND

P. O. Box 1899, Station F, Portland, Oregon

Chairman—George C. Dierking, Production Manager, Steel Tank & Pipe Co. of Oregon
Secretary—C. W. Hopp, P. O. Box 1899, Station F, Portland, Oregon

CANADIAN

933 Bay Street, Toronto

Chairman—Fred H. Williams, Canadian National Railways
Secretary—Campbell Bradshaw, Executive Editor, Engineering Times, 933 Bay Street Toronto

AMERICAN WELDING SOCIETY
ESTABLISHED 1919
JOURNAL

Volume 8 JUNE, 1929 Number 6

Annual Meeting

The Annual Meeting held on April 24 to 26 was considered by all to be the greatest in the history of the Society. Five technical sessions were held at which some 20 technical papers were presented. Discussion was spirited at times and generally constructive.

There was a registered attendance of over 200 people, including members of the Society and guests interested in the technical aspects of welding. Most of the papers were printed in advance in the April issue of the JOURNAL. The remainder of the papers will be published in the June and July numbers.

The meeting was formally opened by a business meeting at which the president presented an annual report summarizing briefly the progress made by the Society in its various activities. A copy of the report is published elsewhere in this issue. F. M. Farmer, as chairman of the Board of Awards, for the Miller Medal gave an account of the history of the medal and announced that the 1927 medal was awarded to Professor C. A. Adams and the 1928 medal to J. H. Edwards. A complete account of the award is given elsewhere in this issue.

The Board of Directors held their annual meeting at the Engineers' Club on Wednesday evening. This meeting was preceded by a dinner. At the board meeting committees and officers were appointed for the coming year. Consideration was also given to arrangements for perpetuating the Samuel Wylie Miller Medal. A new committee was appointed to prepare specifications for qualification tests of welders for various classes of work.

The annual dinner of the Society set a new record for success and attendance (264 members and guests). The dinner, entertainment and prize contests were enjoyed by all.

The annual meeting of the American Bureau of Welding was held on Friday, April 26, at which time officers were elected and progress reports rendered by the various research committees. The meeting of the Bureau was followed by a meeting of the Structural Steel Welding Research Committee.

New Officers
American Welding Society
1929-1930

At the Annual Meeting of the Society the election of the following officers to serve for the coming year was announced:

President—F. T. Llewellyn, U. S. Steel Corporation.

Senior Vice-President—A. E. Gaynor, J. A. Roebling's Sons Company.

Divisional Vice-Presidents — Southern Division: George Bird, Bird-Potts Co., Inc. Pacific Coast Division: J. S. Beall, Beall Pipe & Tank Corp.

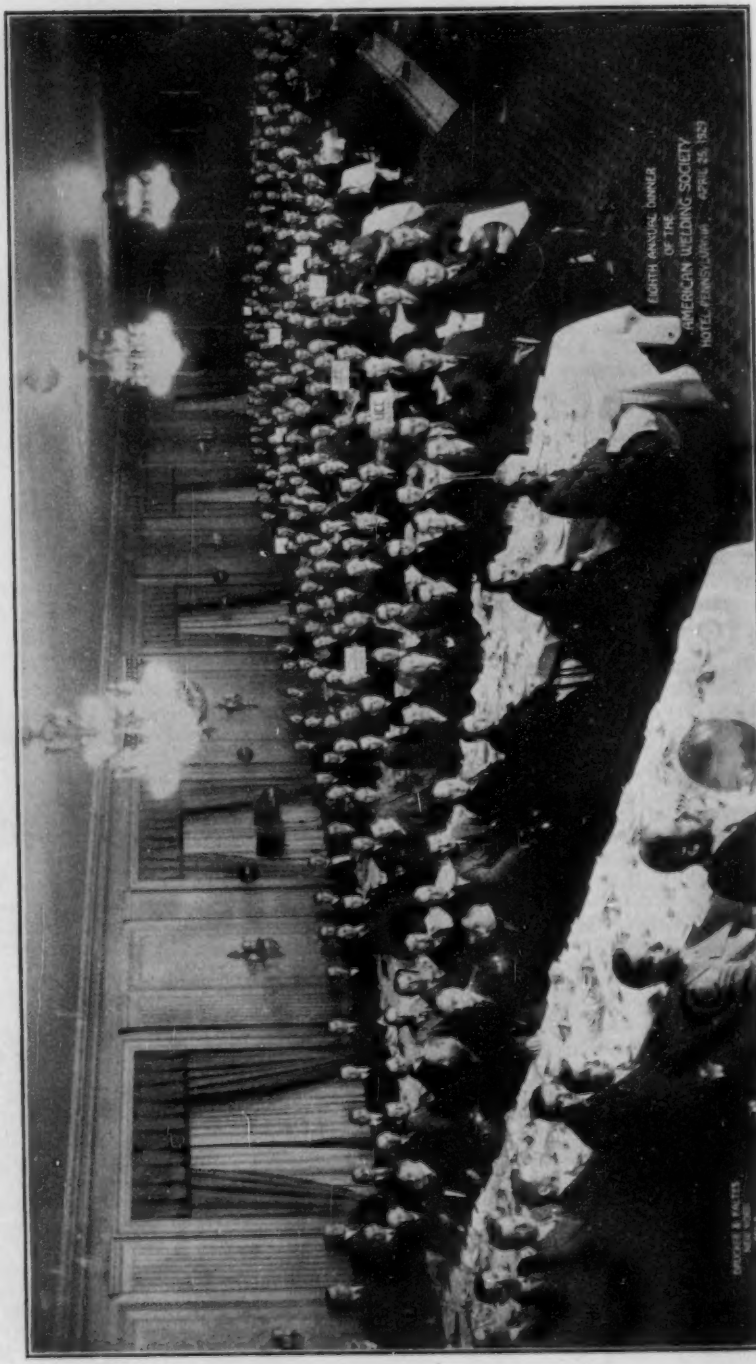
Directors at Large—C. A. Adams, Harvard University; H. M. Hobart, General Electric Company; A. G. Oehler, editor, Railway Electrical Engineer; J. W. Owens, Newport News Shipbuilding & Dry Dock Co.

Officers appointed at Board of Directors' meeting, April 24, 1929:

Treasurer—C. A. McCune, American Chain Company.

Secretary and Assistant Treasurer—M. M. Kelly, American Welding Society.

Executive Committee—F. T. Llewellyn, chairman, United States Steel Corporation; J. J. Crowe, Air Reduction Sales Company; J. H. Deppeler, Metal & Thermit Corporation; D. H. Deyoe, General Electric Company; E. H. Ewertz, consulting engineer; F. M. Farmer, Electrical Testing Laboratories; G. D. Fish, consulting engineer; A. E. Gaynor, J. A. Roebling's Sons Company; Ernest Lunn, Pullman Car & Mfg. Corp.; C. A. McCune, American Chain Company; F. P. Mc-


EIGHTH ANNUAL DINNER
OF THE
AMERICAN WELDING SOCIETY
HOTEL PENNSYLVANIA, APRIL 25, 1923

Kibben, consulting engineer; J. W. Meadowcroft, E. G. Budd Manufacturing Company; A. G. Oehler, Simmons Boardman Publishing Company; H. S. Smith, Prest-O-Lite Company; H. L. Whittemore, Bureau of Standards.

Bureau Offices Elected for Year 1929-30

Director—
C. A. Adams, Harvard University.
First Vice-Director—
H. L. Whittemore, Bureau of Standards.
Second Vice-Director—
A. D. Risteen, Travelers Insurance Co.
Secretary—
W. Spraragen.
Executive Committee —
C. A. Adams, chairman, Harvard University.
W. Spraragen, secretary.
J. H. Deppeler, Metal & Thermit Corp.
J. H. Edwards, American Bridge Company.
E. H. Ewertz, consulting engineer.
F. M. Farmer, Electrical Testing Laboratories.
H. M. Hobart, General Electric Company.
F. T. Llewellyn, U. S. Steel Corporation.
C. A. McCune, American Chain Company.
W. B. Miller, Union Carbide & Carbon Research Laboratories.
A. D. Risteen, Travelers Insurance Company.
E. M. T. Ryder, Third Avenue Railway System.
H. L. Whittemore, Bureau of Standards.

American Welding Society

Report of the President for the Year Ending March 31, 1929

(*Presented in abstract at the Annual Meeting of the Society, April* 24, 1929.)

Membership—Since the organization of the Society in March, 1919, each year has seen a steady increase in its membership. This year it is pleasing to report that the 1000 mark has been passed, and that the Society now numbers 1012, a net increase for the year of 99 (10.8 per cent). Class D was the only one to show a net loss numbering 3 (1.4 per cent). Class A remains at 47, one lost member having been replaced by one new one. Class B was increased by 35 (10.2 per cent). Class C by 61 (20.4 per cent), and Class F by 7 (64 per cent). There was no change in Class E which embraces honorary members. The ratio of gross losses to gains was 62 per cent which, while higher than we should like, is some improvement over the 75 per cent ratio reported a year ago. The increase in Class F doubtless reflects interest in welding at the technical colleges. A table of present class membership compared with that of the preceding year is given.

Class	*Membership March 31* 1929	1928
(A) Sustaining Members	47	47
(B) Members	378	343
(C) Associate Members	360	299
(D) Operating Members	207	210
(E) Honorary Members	3	3
(F) Student Members	17	11
Total	1012	913

Finances—For the year ending March 31, 1929, receipts were $35,017.33, expenditures, $33,773.69, the surplus being increased by $1,243.64. Receipts were $2141 more, and expenditures $1022 less, than during the preceding year. The Reserve Fund has been increased from $6,762 to $8,006, of which $5,269.50 is invested in bonds.

Meetings—The Annual Meeting was held in New York in April, 1928, with a registered attendance of 190 people. It included three technical sessions as against two the previous year and five scheduled for the present year. An informal lunch, and a still less formal stag dinner, were the social features.

The Fall Meeting was held in Philadelphia in October, 1928, with a registered attendance of 300 people. It included five technical sessions, a special conference on fundamental research, inspection trips, and entertainment for the ladies. The policy of cooperating with the American Society for Steel Treating was continued in connection with the exhibits of welding and cutting equipment, and all afternoon sessions were held at the exposition hall.

Most of the 13 Sections had very satisfactory local meetings throughout

the year, the plan of joint meetings with affiliated technical societies and college symposia being especially fruitful.

Sections—The 13 Sections of the Society continue, with marked activity in some localities. Members located in Texas are agitating the formation of a new Southwestern Division, and in view of their distance from the seats of existing divisions they have been encouraged. The advisability of creating a new division will be considered by the Board of Directors at its meeting this week. Evidence accumulates that no one Section can function efficiently over too large an area.

Journal—During the past year the 12 issues of the Journal totalled 1300 pages as against 1324 the previous year. There has been a recent reduction in number of pages to offset the reduced space taken by one large advertiser. A tabulation of Journal space during the past two years is given:

	Number of Pages	
Matter	*Vol.* 6	*Vol.* 7
Editorial	122	160
Technical	970	851
Advertising and Circular	232	289
Total	1324	1300

Annual Exposition—A Welding and Cutting Exposition in conjunction with the American Society for Steel Treating has been repeated along the lines followed for the two previous years. Accordingly last year the exposition coincided with the Fall Meeting at Philadelphia. There were 32 exhibitors of equipment and products representative of our manufacturing interests. A similar joint arrangement is being made for the 1929 Fall Meeting at Cleveland.

American Bureau of Welding—As in former years, the work of the Bureau appears in the activities of its several research committees. One new committee (Standard Tests for Welds) has been added, and the organization of another (Fundamental Research) has been completed. The committees on Welded Rail Joints, Structural Steel, Pressure Vessels, and Welding Wire Specifications have continued their work.

The Committee on Welded Rail Joints is probably entering the last phase of its activity. During the past year its work included repeated impact tests on rail joints made under a variety of conditions, some preliminary tests to evaluate the effects of preheating and post heating; the testing of some special joints and the testing of full size specimens aiming to secure a type of joint and method of welding that would improve the top seams in the seam welded type of rail joint. Progress Report No. 6 was published in the October, 1928, issue of the Journal, and also as a separate bulletin containing 89 printed pages. It included strain gage investigations on rail joints and on flat plates to study the effect of distortions and stresses caused by welding; results of tests on special types of rail joints; additional shear test results; repeated impact tests; and preliminary investigations on preheating and annealing.

The Structural Steel Committee, having collected one half of the funds pledged for its program, has made considerable progress. It will be recalled that a series of 342 pilot tests were made for the guidance of the committee at the University of Toronto by Professor Peter Gillespie. The results of these tests were reprinted in the March, 1929, issue of the Journal from the University of Toronto Bulletin No. 8. They served admirably the purpose for which they were intended. Final specifications for the preparation and testing of program specimens were published in pamphlet form, and also in the November, 1928, issue of the Journal. Orders were placed with the three rolling mills donating the steel required, and this material has been shipped to the forty fabricating shops volunteering to prepare specimens. Each welder is required to qualify by welding five plates which are cut into twenty coupons, and these coupons are tested. Many of the qualifying specimens have been shipped to cooperating laboratories and tested with results that indicate reliance can be placed on the output of commercial shops, provided the welding is done under proper control. The program specimens will now be prepared and tested, and it may be expected that the early future will see practical results in the form of a body of reliable data upon which unit working stresses in the design of welded structures can be based with safety.

The work of the Pressure Vessel Committee has been handicapped by an apparent lack of interest on the part of most of the tank manufacturers. The Committee has simplified its program with the view of meeting the requirements of the Boiler Code Committee along lines that would be supported by industry. The apparatus manufacturers have offered to provide some of the tanks and half the cash needed, but so far sufficient cooperation elsewhere has not been pledged to warrant the committee going ahead, except on a still further reduced basis.

Of the newer activities of the Bureau one of the most important is the stimulation of fundamental research at the technical schools of leading universities. A conference with ten of the cooperating professors was a high spot at the Fall Meeting in Philadelphia. The topics under investigation include:

Carnegie Institute of Technology—Effect of Heat of Welding on Adjacent Base Metal.

Leland Stanford University—Properties of Welds at Elevated Temperatures.

State College of Washington—Fatigue Properties of Welded Joints.

Ohio State University—Effect on Welds of Certain Gases in Base Metal Steel.

University of Toronto—Effects of Current Density and of Micro-structure on Strength of Welds.

Massachusetts Institute of Technology—X-Ray Examination of Welded Joints.

Lehigh University—Physics of the Metal Arc and of Electrodes as it Affects Weld Properties.

(Catholic University) (Rensselaer Polytechnic Institute)—Internal Stresses Caused by Welding.

University of Pittsburgh—Distribution of Shear in Side Welds.

In the September, 1928, issue of the Journal two important reports were published describing the Leland Stanford studies at elevated temperatures. Plans are under way for a second conference at the Fall Meeting of the Society in Cleveland early in September.

The Committee on Welding Wire Specifications is planning to ascertain from industry if there is need for a revision of the present specifications.

The Committee on Standard Tests for Welds was recently appointed to bring existing standards up to date.

Codes—In cooperation with the United States Bureau of Standards procedure specifications for making aircraft joints were prepared by a Bureau committee, and published in the December, 1928, issue of the Journal.

A procedure specification for the fusion welding of pressure vessels has been prepared by a committee of the Society at the request of the A.S.M.E. Boiler Code Committee. With the approval of the Society's Executive Committee and Board of Directors its use has been recommended to the Boiler Code Committee. Another Society committee is cooperating with the Sub-Committee on Welding of the Boiler Code Committee in the formulation of answers to inquiries concerning welding that are presented by industry to the latter committee.

The Committee on Building Codes has prepared a code for the welding and cutting of structural steel which has been approved by the Society's Executive Committee and Board of Directors, and is now in the printer's hands. This code should meet an insistent demand from public bodies for conservative regulations that will permit welding in city buildings. The same committee is preparing codes dealing with the class of low pressure tankage and piping that is used in buildings.

A Committee on Nomenclature is about ready to submit a comprehensive report on welding and cutting nomenclature, with definitions and symbols. Such a document will go far to meet the growing needs of the industry.

The Society has been invited by the American Committee of the World Engineering Congress, to be held at Tokio, Japan, this fall, to prepare a paper on welding. In response a Committee has been actively at work, making its survey from the standpoint of use rather than process, and a report is expected shortly.

Other Committees are engaged on various assignments from which valuable results should accrue in the near future.

Conclusion—The Society is in a generally healthy condition. As stated by my predecessor a year ago, it is increasingly regarded as authority on all matters pertaining to the newer methods of welding and cutting.

While it continues in large measure to depend on individual industries for financial support, its purpose is to favor only those objects that make for the general good of all. The Society is no stronger than its members. It can do nothing except through the coordinated accomplishment of each member. Its future success as an organization depends on the extent to which each member is willing unselfishly to labor, not for his own ends, but with more far-sighted vision for the benefit of the industry as a whole.

Respectfully submitted,
F. T. LLEWELLYN,
President.

Report of Board of Trustees, Samuel Wylie Miller Medal

This medal was established in 1927 by the late Samuel Wylie Miller, a past-president of the Society, to be awarded annually during his lifetime for conspicuous contribution to the advancement of the welding art.

The original conditions under which the award was to be made prescribed that the contribution should be described in a paper to be submitted to the Board of Trustees. As no paper was presented to the Board which was considered sufficiently meritorious to warrant the award of the first medal, the one for 1927, the Board, with the consent of Mr. Miller, changed the conditions of the award so that the medal could be "awarded annually for any meritorious achievement which in the judgment of the Board of Trustees has contributed conspicuously to the advancement of the art of gas fusion welding and cutting or the art of electric arc fusion welding and cutting." The Board takes pleasure in announcing that under these modified conditions it has awarded the medal for both 1927 and 1928.

The Samuel Wylie Miller Medal for the year 1927 is awarded to Comfort Avery Adams. Prof. Adams, Lawrence, professor at Harvard University, is one of the leaders in the American engineering profession, as evidenced by the many honors which have been conferred upon him, such as the presidency of the American Institute of Electrical Engineers, the chairmanship of the John Fritz Medal Board, the chairmanship of the Edison Medal Board, the chairmanship of the General Engineering Committee of the Council of National Defense during the war, the chairmanship of the Engineering Division of the National Research Council and the chairmanship of the American Engineering Standards Committee.

It is, however, the special field of welding with which we are concerned, but we here find that Prof. Adams has also been a conspicuous leader from the beginning of organized effort to advance the art of welding during the war. He was Chairman of the Welding Committee of the Emergency Fleet Corporation during the war and was responsible for the movement which resulted in the organization of the American Welding Society in 1918. He was its first president and has been director of the Society's research activities since its inception. Prof. Adams has continuously given freely of his time and of his energy during all of these years to the advancement of welding as an engineering tool and to him belongs much of the credit for the elevation of welding to the position it occupies today as one of the important mechanic arts. This is a meritorious achievement which has contributed conspicuously to the advancement of the whole welding art and which the Board considers entitles Prof. Adams to the honor of being the first recipient of the Miller Medal—the medal for the year 1927.

The 1928 Samuel Wylie Miller Medal is awarded to James Harvey Edwards. Mr. Edwards is also eminent in the American engineering profession as evidenced by his having been a director of the American Society of Civil Engineers, a trustee of Cornell University and by the position which he now holds, Chief Engineer of the American Bridge Company.

Mr. Edwards has taken a conspicuous part in the application of the welding processes to steel structures. His energetic interest in, and encouragement of, this particular application of welding along sound and conservative engineering lines has had great influence in advancing the art. As Chairman of the Structural Steel Committee of the American Bureau of Welding he is primarily

responsible for the success with which a research program is being carried out that promises to be of the greatest value to the steel fabrication industry. Mr. Edwards' contribution to the marked advancement which has taken place in the application of welding to steel structures is a conspicuous achievement for which the Samuel Wylie Miller Medal for 1928 is awarded.

It is a matter of considerable satisfaction to the members of the Board that Mr. Miller was present by invitation at the meeting held shortly before his death at which these awards were agreed upon and that the decisions were heartily approved by him.

Respectfully submitted,

E. H. EWERTZ,
C. A. MCCUNE,
F. M. FARMER,
Chairman.

April 24, 1929.

Welding—A New Design Medium

Reprinted from April 18, 1929, issue of *Engineering News-Record.*

Acceptance of structural welding as a new design medium goes along more slowly than might be expected. The mere use of welding to make structural joints has, on the other hand, enjoyed a phenomenal increase. Between these two methods of measuring growth there is a vast difference, and it is the development of a proper appreciation of this difference that now confronts the structural fraternity as a fundamental problem. Analysis of a majority of the currently welded structures reveals few instances reflecting the unhampered thinking that a new design medium such as welding should offer.

From its beginning the art of welding has been retarded, first by its original conception as a form of magic that would eliminate riveting entirely, and second by hasty assumption that such elimination is possible merely by substituting weld beads for rivets. That welding will not and should not be regarded as a substitute for riveting but only as a supplementary method of steel connection which will effect economies over rivets under certain easily recognizable conditions is gradually being appreciated. The second handicap to welding progress—failure to forget riveting precedents—is still very active, representing perhaps the greatest single obstacle that the welding art must overcome.

For instance, the fact that continuity is possible in riveted construction only at a considerable expense has led many designers to neglect it when welding is being considered. Riveted beam-to-column connections which utilize top and bottom angles and a web connection have caused welding designers to duplicate the practice blindly. The elimination of gusset plates with welding has been more readily accepted, as has the substitution of plates for angles as plate girder stiffeners. But by and large the customs and precedents of riveted practice have too often been reflected in high welding costs.

In view of such circumstances the recently built Hot Springs Hotel addition (see *Engineering News-Record* of March 28, p. 490) deserves careful attention as a structure in which an honest attempt has been made to utilize welding on the basis of its own merits alone. Briefly, the outstanding characteristic of the structure was the development of ingenious forms of column splice and beam-to-column connection excellently suited to both shop and erection requirements. Furthermore, the floor-beams were supported on clip angles welded to the column in the shop instead of by shear welds between the webs of the beams and the column faces. No attempt was made to use welding where rivets or bolts would serve better. The work in all its phases represents intelligent application of highly developed skill.

Such practice reflects original welding thinking of a high order and should be emulated. We need more structures which have been designed for welding and fewer upon which welding has merely been used. How well this objective is attained will determine the progress of the next few years.

Welding Information*

Knowledge of the design principles of fusion welding of structural steel is gradually being increased. What is no less important, this knowledge is being more widely disseminated. The large arc-welded structures erected in the past few years have, by and large, been conservatively and carefully de-

*Reprinted from March 14, 1929, issue of *Engineering News-Record.*

signed. But many smaller welded structures are standing in spite of their design rather than because of it. This situation can be satisfactorily cleared only by a wider appreciation of proper design brought about by a sustained growth in the literature of welding. Happily, such a growth is becoming apparent. At the last convention of the American Institute of Steel Construction Fred T. Llewellyn, president of the American Welding Society, read an important paper which collated and brought up to date our present knowledge of structural welding; this paper will be published in a near future issue of this journal. The structural steel welding committee, which has carried out a remarkable program of tests on welded joints, will soon issue its long-awaited specification. In this issue there is published an electric-arc welding specification prepared by Frank P. McKibben, planned to benefit those engineers who have been handicapped because of lack of information, and also to guide the framers of city building codes and others who are considering the adoption of arc welding. As the first specification of its kind it forms an important contribution to the available literature on the subject and deserves wide attention. In these several ways is the literature of structural welding assuming the proportions that are necessary for the proper development of the art. Obviously welding is not to be expected to replace riveting altogether; certainly it is not a panacea for all the present-day ills of the structural designer and fabricator. But it has demonstrated its worth as a process worthy to be included in the structural engineer's kit bag; and therefore the profession cannot afford the setback to its acceptance that failure of a poorly designed structure would inevitably bring about. One of the surest safeguards against this is a wide appreciation of sound and careful design.

Arc Welding Influences Machine Design*

Progress in arc welding is rapidly approaching a point where it may be regarded as a major influence in machine design. All new methods in engineering are exposed to the dangers of overenthusiasm, but if the field of improved processes is properly analyzed from time to time and sweeping conclusions from premature data are avoided, advances in practice are sure to be steady and ground gained will seldom be lost. Thus at the recent industrial heating electric conference in New England J. F. Lincoln pointed out that the application of arc welding to manufacture is not only the utilization of a new production tool, but it is also the development of a new and fundamental manufacturing process and should be so approached.

Until new tools and new standards were made available high-speed steel was of comparatively small importance. Alloy steel was of little value until designs were modified to take advantage of its greater efficiency. Similarly, if arc-welded steel is to be used in its proper sphere, old conceptions of designing must be revised. This applies to structural work of many kinds, and it is particularly desirable to avoid the limitations forced upon old methods by various changes due to processing when undertaking the design of structures to be arc-welded. Many structural designs represent changes brought about by difficulties in insuring adequate strength in castings after shrinkage or in obtaining proper shape in view of molding limitations. Warping of castings during machining may also affect the ultimate design. For such reasons the designer of an arc-welded machine base should make a fresh start, apportioning his material according to the selected loads and deflections and getting the benefit of the accurate work associated with this method. For example, where an arc-welded steel base is made of the same depth as a cast-iron structure, all sections may be 40 per cent as heavy without sacrifice of stiffness; in the design of containers the difference between welded and riveted joint strength will often cut down the amount of material needed by 20 to 50 per cent and sections may be reinforced.

Errors in designing for arc-welded structures are usually due to delays in getting started, to hasty efforts without proper design, equipment and training, absence of engineering analysis and supervision, hesitation when a new design properly engi-

*Reprinted from March 16, 1929, issue of *Electrical World*.

neered first comes through because of its lightness of weight and "spindly" appearance, and fixed ideas as to the low cost of operating one's own foundry. The importance of training men to supervise practice properly is vital in the present stage of the art, and as large electric welding jobs multiply the ubiquitous machine designer will be able to draw upon the experience of others to a greater degree.

Program of Welding Conference held at the L. C. SMITH COLLEGE of APPLIED SCIENCE Syracuse University Syracuse, N. Y. April 4-5-6, 1929

The purpose of this conference was to bring together a group of men interested in the latest developments and applications of welding in its various forms.

A number of manufacturers of welding equipment displayed some of their latest products at the conference.

Throughout the course of the conference tests on welded specimens were conducted in the Materials Testing Laboratory of the college.

PROGRAM

THURSDAY, APRIL 4

Morning

9 a. m.—Oxy-Acetylene Welding and Cutting in Production—R. W. Boggs, engineer, The Linde Air Products Co., New York, N. Y.

10 a. m.—Open discussion and demonstrations.

10.30 a. m.—Welding for the Plumber and Steam Fitter—R. F. Helmkamp, engineer, The Air Reduction Sales Co., New York, N. Y.

11.30 a. m.—Open discussion and demonstrations.

12 m.—Recess for lunch.

Afternoon

2 p. m.—Automatic Metallic Arc Welding Applications—M. W. Brewster, engineer, The General Electric Co., Schenectady, N. Y.

A discussion of the latest developments in process welding in industrial plants.

3 p. m.—Open discussion and demonstrations.

3.30 p. m.—The Development of Arc Welding as a Manufacturing Tool—E. Vom Steeg, Jr., welding specialist, The General Electric Co., Schenectady, N. Y.

In which was shown how welding is rapidly replacing other methods of manufacture.

4.30 p. m.—Open discussion and demonstrations.

FRIDAY, APRIL 5

Morning

9 a. m.—Modern Manufacturing with an Arc Welder—J. S. Roscoe, engineer, The Lincoln Electric Co., Cleveland, Ohio.

10 a. m.—Open discussion and demonstrations.

10.30 a. m.—The Application of Welding to Pipe Line Installations—E. R. Benedict, engineer, The American District Steam Company, North Tonawanda, N. Y.

11.30 a. m.—Open discussion and demonstrations.

12 m.—Recess for lunch.

Afternoon

2 p. m.—The Economic Side of Arc Welding of Structural Steel—Gilbert D. Fish, consulting engineer, The Westinghouse Electric & Manufacturing Co., New York, N. Y.

In which was pointed out the cost saving possibilities in the arc welding of structural steel.

3 p. m.—Open discussion and demonstrations.

SATURDAY, APRIL 6

Morning

9 a. m.—Thermit Welding—Its Place in Industry—R. L. Browne, New England District Sales Manager of The Metal & Thermit Corporation, Jersey City, N. J.

10 a. m.—Open discussion and demonstrations.

Autogenous Welding Serving the Chemical and Process Industries*

By T. McLean Jasper†

THE subject of autogenous welding is one which is engaging the attention of steel fabricators to such a degree that the various processes as a whole promise to replace forge welding and riveting in the building of heavy walled containers and pressure vessels for the oil, chemical and other process industries.

Autogenous welding as a term covers a very large variety of processes. Each of these processes has certain limitations which make it difficult to produce ideal results. Such limitations can be evaluated only after conscientious and painstaking study and work.

In order that the cause of welding as a whole may be furthered, it is not only necessary that the existing shortcomings of the various processes are frankly admitted but also that claims are limited to such results as can be consistently obtained. In addition, it is only through intelligent study and honest effort that improvement of the art of welding can be achieved.

If one might outline the ideal fundamental requirements of welding as applied to containers and vessel construction it would be this:

The production of a welded joint which is as strong, as ductile, and as resistant to corrosion as the metal which it joins. This also involves the principle that the welding operation shall not damage or reduce in strength the metal adjacent to the welded joint.

The quality factor outlined in the above requirements means that the deposited metal must be free from embrittling agencies, such as oxides and nitrides, and that the metal also be quite free from blowholes and inclusions. It also means that the act of welding should not anneal the metal adjacent to the weld, which would result in a reduction of the strength of the piece, nor should it overheat the metal under conditions which create grain growth, such as is commonly associated with the overheating of low carbon steels.

In certain processes of autogenous welding it is very difficult at the present general state of development to avoid producing one or more of the harmful conditions outlined above and for this reason such processes will in time either be greatly modified and improved or give way to such processes as can be safely applied to pressure vessel building.

One of the most fruitful avenues for the improvement of the various results obtained by welding lies with the decrease or elimination of the use of men in the fatiguing operation of handling the arc or torch. While it is believed that hand operation in welding can, for relatively

*Paper presented before Annual Meeting, A. W. S., April, 1929.
†Director of Research, A. O. Smith Corporation, Milwaukee, Wis.

short periods, be performed as good as and, in some operations, better than automatic methods, yet the fatiguing effect on a man of the tedious process of production welding tends toward inconsistent results which sometimes may be very poor.

This brings us to the matter of design of joints and the reasons why ductility and strength in welding are so essential, especially for pressure vessel construction.

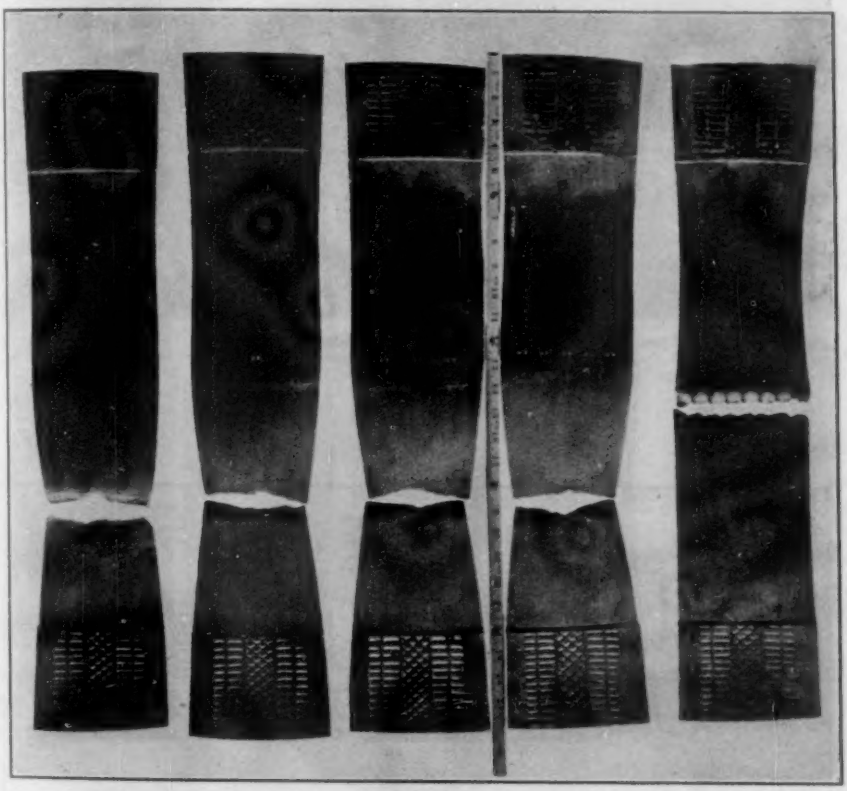


FIG. 1—TENSILE TEST SPECIMENS CUT ACROSS WELD JOINING PLATES OF 6 INCH THICKNESS

It is believed that the best design of joints is one which does not substantially increase the thickness of the metal at the joint. This makes it essential that the deposited metal shall be as strong per square inch as the metal which it joins together. If this is true, then it is equally essential that the weld metal should be ductile so as to appropriately fit into the joining of two pieces of metal which are ductile.

In the production of vessels of 2 in. wall thickness and over, it is of even greater importance that the welded joint has all of the desirable qualities heretofore described. This because of the added stiffness of a thick walled section as compared to a thin walled section.

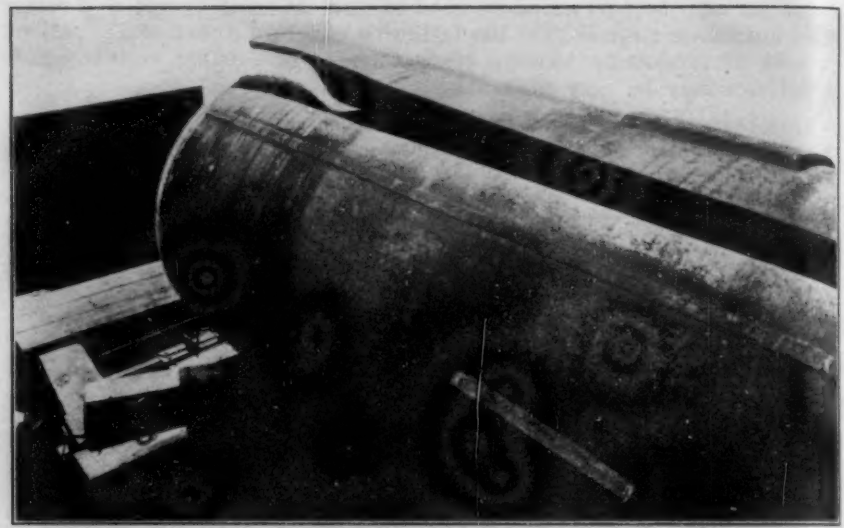


FIG. 2—HYDROSTATIC TEST OF PRESSURE VESSEL TO DESTRUCTION. FRACTURE STARTED IN THE KNUCKLE OF ONE HEAD AND THE VESSEL SPLIT LONGITUDINALLY. AT NO POINT WAS THE SPLIT CLOSER TO THE WELD THAN 14 INCHES

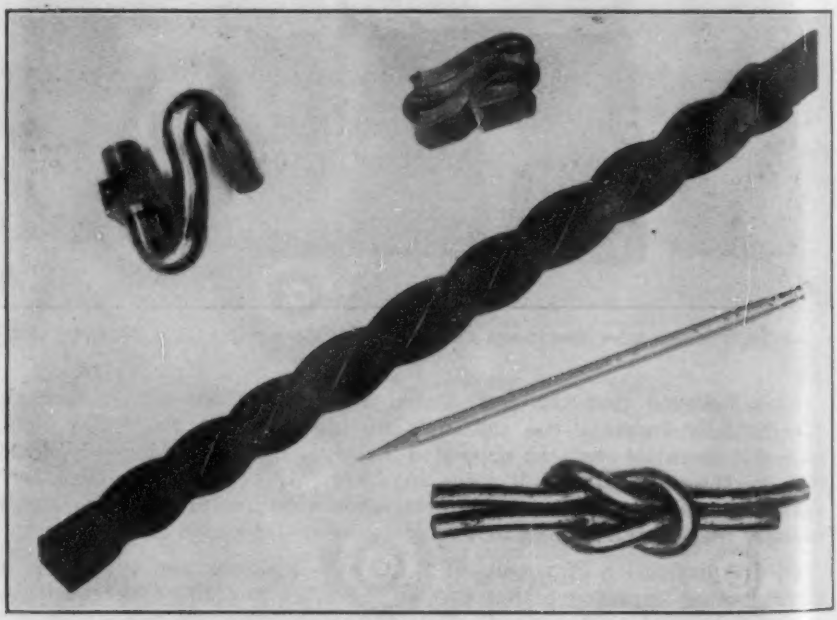


FIG. 3—SPECIMENS CUT ENTIRELY FROM DEPOSITED WELD METAL AND BENT COLD, SHOWING THE REMARKABLE DUCTILITY OF THIS TYPE OF WELD

It might be appropriate to state here that the logical aim is to produce a joint which is made of stronger metal than the plates joined. If this can be done without reducing the strength of the metal adjacent to the joint, and if, at the same time this weld has approximately the same ductility as the plate, then the security of joint and vessel is assured. Of course, this is only true providing the design is properly executed and the material appropriately selected.

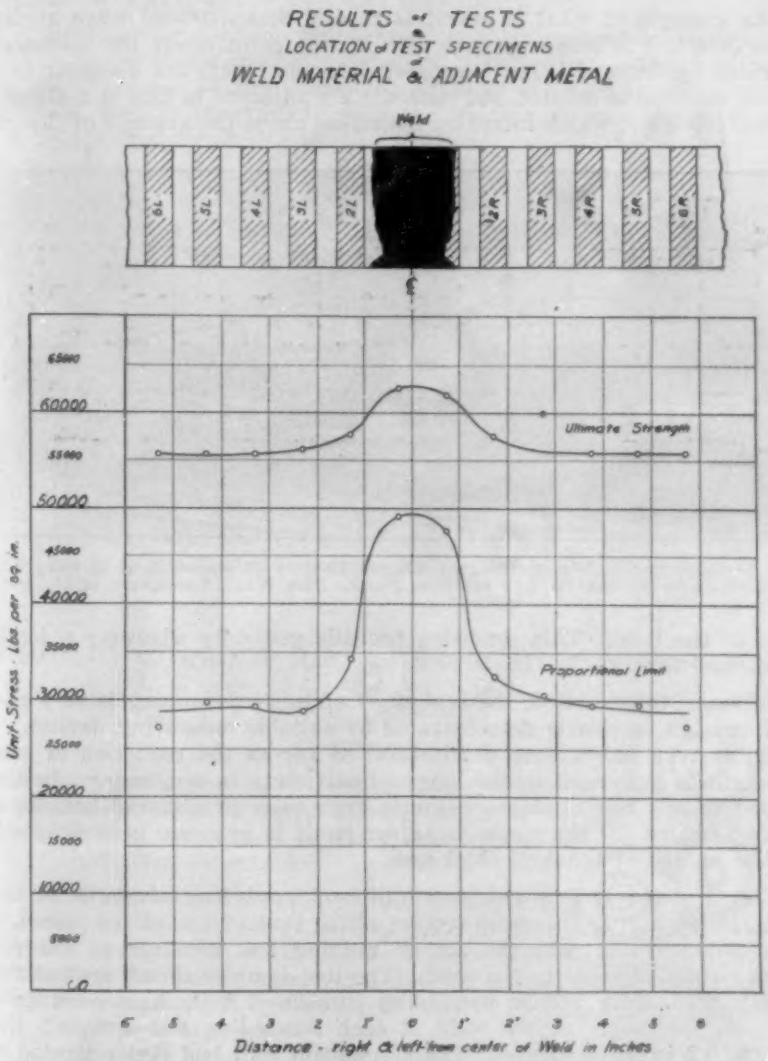


FIG. 4—TEST RESULTS ON SPECIMENS FROM WELDED PLATES 2⅝ INCHES THICK, SHOWING THAT THE WELD AND THE ADJACENT METAL IS STRONGER THAN THE ORIGINAL PLATE. TEST SPECIMENS WERE CUT AT ONE INCH INTERVALS PARALLEL TO THE WELD AND PULLED IN THE SAME DIRECTION

The company with which the author of this paper is associated has built nearly one thousand large vessels of welded construction. The average weight of the vessels is about 120,000 lb. each and the heaviest weighs 396,000 lb. In the building of these vessels there are no overlapping joints and therefore the weld is called upon to carry equal stress with the plates joined. The effect of overlapping at the joints in thick walled vessels is exceedingly detrimental, because it results in stress intensification in the steel adjacent to the joints.

An example of what is meant is readily demonstrated when an inner tube of a tire is blown up with air. At the point where the thickness is doubled by one end being telescoped into the other, the diameter is less when the tube is inflated and immediately adjacent to this is a stress reversal tendency, which increases the stress above the average of the other

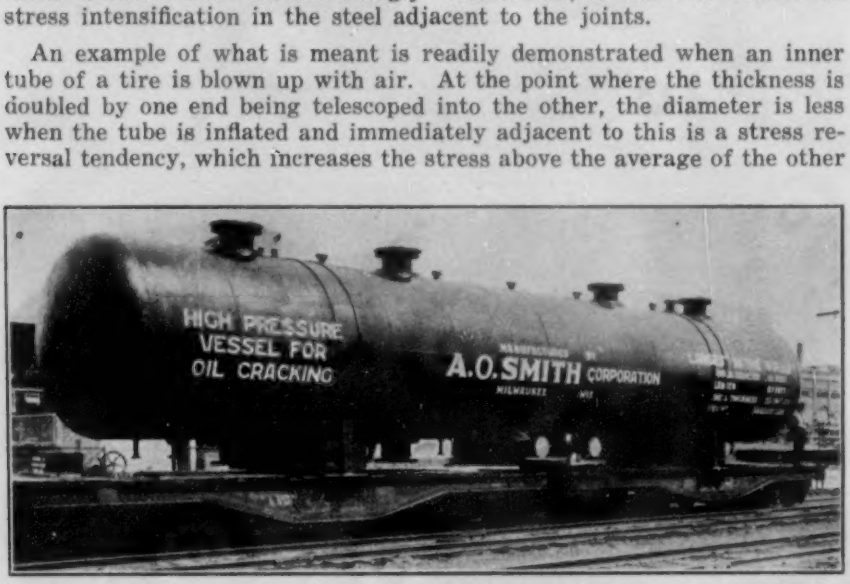


FIG. 5—THIS VESSEL WEIGHS NEARLY 400,000 LBS., IS 67 FEET LONG, 10 FEET INSIDE DIAMETER AND IS OPERATING AT 900 DEG. FAHR. THE WALL THICKNESS IS 3½ INCHES

part of the tube. This condition prevails generally wherever a joint is thickened up.

In vessel construction, the real effect of this overlapping is very material and can be clearly demonstrated by suitable measuring devices. Its effect is very much more detrimental so far as the reduction of vessel strength is concerned in the longitudinal joints in a cylinder. In thick walled vessels this tendency becomes even more pronounced because the force required for the vessel to adjust itself to pressure is in proportion to the square of the wall thickness.

Fig. 1 demonstrates the possibility of producing strength of weld without increasing the cross-section above that of the plates joined. It also demonstrates that the act of welding has not injured the plate immediately adjacent to the weld. The test samples shown are cut from a plate 6 in. thick and an increasing number of holes have been drilled through the center of the weld in each succeeding test sample. Each hole is 0.2 in. in diameter. The subsequent pull test demonstrated the strength of the weld as compared to the strength of the parent metal.

Fig. 2 demonstrates that the vessel when constructed acts in a manner

similar to that intimated in the tests represented in Fig. 1. This shows a 40 foot vessel, 6 ft. in inside diameter, with 2 in. thick walls and represents a test to destruction.

The ductility of the weld is indicated by Fig. 3, which shows specimens made of deposited all-weld material, which has been cut from production welds. These specimens have not been heat treated in any manner after welding and were bent and twisted cold without fracture.

Fig. 4 demonstrates that the metal strength is not reduced immediately adjacent to the weld but rather is increased. This effect is obtained by making judicious use of the quenching effect of the cold metal in the plates joined, and by progressing with the welding at such a rate that there is no overheating of this metal.

The possibility of the application of such welding is shown in Fig. 5. This represents a vessel 396,000 lb. in weight. It might be said that with welding of this kind available, designing engineers can obtain structures of much more improved shape and can design vessels with only 70 per cent of the material necessary to carry equal loads with the best type of riveted construction, even when used in conjunction with seal welds. The general tendency in welding is to use the same thickness of vessel wall as with riveted construction, which results in a vessel more than 40 per cent safer to operate.

This saving of material or increase of safety is accomplished by using improved designs of heads, reinforcing of openings, and by producing a joint without increased thickness, which will be sufficiently ductile and stronger than the metal joined.

It must be understood that the above figures and description of accomplishment apply to a patented process welding used by our Company.

How to Organize and Operate an Industrial Welding School*

J. C. LINCOLN†

IT is rather presumptuous to head a paper "How to Organize and Operate an Industrial Welding School," and it is not our intention to tell how to do this, but merely to relate our experiences and to give the methods of operating our school.

During the war we were asked by the United States Government to train a number of men in arc welding. These men were to be sent with supply trains to the A. E. F. in France. Some forty or fifty operators were trained in the fundamentals of arc welding, but unfortunately we do not believe ever reached France, as the end of the war eliminated the necessity for their being sent.

At that time there were comparatively few experienced operators and various concerns to whom we sold welders, knowing of the training

*Paper presented before annual meeting, A. W. S., April, 1929.
†Chairman of the Board of Directors, Lincoln Electric Company, Cleveland, Ohio.

which we were giving Army men, asked if it would be possible for them to send in some of their own men to receive the same training. This was done and so many requests of this nature were received that it was decided to continue the Welding School, and since that time it has been in continuous operation. The call for this training has increased so that it has been necessary—every year or so, to increase the facilities in the school.

After we had announced to the purchasers of our equipment that they were privileged to send men to be trained, we began to receive requests from other men who wished to learn arc welding as a trade and who were desirous of taking a course entirely on their own responsibility. Therefore very shortly after the end of the war we instituted the policy of extending to any industrious individual the opportunity of attending the school. To those who apply for entrance, we reply in the following language, which perhaps explains the method of operation better than in any other way:

> The Lincoln Electric Company extends to industrious individuals the opportunity and privilege to visit their Welding School for the purpose of learning the fundamental principles of arc welding. This is really not a school in the ordinary sense of the word, as the instructions given are practical with little theoretical work involved. The usual length of the "course" is about six weeks.
>
> No charge is made for the instructions given or electrical power or other materials used. Similarly no wages are paid.
>
> A deposit of $10.00 is required to cover tools and other materials used, and this amount is returned upon leaving, providing material is returned in good condition.
>
> Anyone taking the "course" is required to obey all rules of the factory, the same as any employee of the company. Also he is expected to stay for the full length of the course or until such time as the welding instructor is satisfied that the student is capable of holding a job as a welder. Factory hours are 7.00 to 11.30 a. m. and 12.00 m. to 4.30 p. m.
>
> Men coming to the school from out of town can secure rooms close to the factory at about $5.00 per week. Meals are usually eaten at restaurants (lunch can be secured at the plant cafeteria), although room and board may be obtained at one or two places.
>
> Anyone wishing to take advantage of this opportunity under the above conditions should write to A. F. Davis for date of entrance."

From the foregoing it will be noticed that the course is entirely a practical one, comparatively little time is given to theorizing and almost the entire time of the operator—while in attendance, is spent on practice work. It is felt that it is better, when an operator leaves our school, to be able to do welding in a thorough-going, workmanlike way than being able to theorize. We attempt to teach the operator to be able to make a good weld and to be able to know that he is making a good weld—when actually welding. At all times we endeavor to stress the point that good welding depends, first—on the operator and that under no conditions should quality of the weld be sacrificed; and incidentally when each operator leaves the school he is asked to sign the Lincoln Arc Welding Pledge to the Industry, although he is not required to do so. For those who are not familiar with this Pledge, it is as follows:

I pledge myself to the following articles:

FIRST. To do all in my power to advance the cause of arc welding.

SECOND. Never to be guilty of knowingly making a poor weld.

THIRD. To report to my superior immediately any weld which I believe is not thoroughly dependable for the service for which it is intended.

FOURTH. To give to my employer, at all times, my best efforts, loyal service and honest workmanship.

FIFTH. To extend all possible assistance to welder operators less proficient than myself.

SIXTH. To strive each day to increase my knowledge and skill in the art of arc welding.

We of course have many enrolled to take the course who do not intend to be operators, but who do wish to be thoroughly familiar with the operators' problems and who also wish to familiarize themselves with the uses of arc welding in its various phases and for design work. These are given the practical course the same as for operators, but in addition are given outside work in the various applications.

We have found it very necessary, in order to keep up the morale of the students enrolled in the school, as well as members of our own organization, to insist that all who take the course maintain the regular factory hours. This is insisted upon and any student who fails to comply with this is automatically dropped from the course, unless special provisions are made with the Instructor.

The Instructor is also given the authority for automatically dropping any student who is not conscientious and who is not attending the school for the one sole purpose of learning to become an operator. We are glad to say that it has only been necessary to drop a very few from the hundreds we have trained—for this reason.

We have found it highly desirable to have thoroughly practical instructors, and it has also been desirable to have instructors who were familiar with gas welding as well as the arc, not because anything is taught in the school in regard to gas welding, but so as to be able to answer any questions which might arise regarding the gas process and to point out the differences between the two.

The course is divided into practically twelve divisions, or lessons, and the amount of time spent on each one depends considerably upon the students as many are able to proceed faster than others.

The following will give a general idea of the phases covered:

Lesson 1. The contact of the arc and its characteristics and manipulations.
Lesson 2. The nature of welding rods and deposited metal.
Lesson 3. The operation and care of the welding machines.
Lesson 4. The nature of vertical and overhead welding.
Lesson 5. Testing of welds for porosity and strength.
Lesson 6. The welding of cast iron and its percentage of strength.
Lesson 7. The advantage and future of carbon arc welding.
Lesson 8. Welding of copper and bronze castings.
Lesson 9. The use and abuse of pressure welding.
Lesson 10. The assistance to the human element of proper welding rod.
Lesson 11. The construction of welded machine tools.
Lesson 12. The simplicity and strength of welding fixtures.

How to Organize and Operate an Industrial Welding School*

N. E. WAGNER†

IN order to establish a permanent industrial welding school, to send out men who will prove a credit to the school, the institution must first of all be impartial and founded on a firm financial basis. It must be guided by a board of unbiased directors who are interested in the advancement and purpose of the school. It must have a staff of competent instructors.

If an independent school for industrial welding only, it should, if possible, be endowed for a sufficient sum to withstand financial trouble. From interest on endowment funds and through regular subscription from those interested in the success of such a school and the tuition charged students, the income for support of the school could be regulated to take care of all needs. The original foundation fund would have to be worked out in a systematic manner. One of the best methods of assuring stability for such a school is to have same established in connection with one of the colleges of a State university or become a part of a reliable engineering school. With such an arrangement the operating expense of the school is not dependent upon individual contributions from the trade at large. Also when such a school is operated within a State institution the tuition could possibly be placed at a minimum, making it possible for men of moderate means to take advantage of such a course. In any event, the rate of tuition should, of course, be established at as low a rate as possible. Tuition and laboratory rates should be made clear so that the student will understand his obligations.

It is necessary that such a school be equipped with the best modern welding apparatus, because a certain amount of practical laboratory training is very essential. Apparatus could possibly be furnished at cost from the manufacturer.

A certain amount of credits from previous scholastic training or entrance examinations should be required for admission to such a school. However, such requirements should be rated as low as possible in order to open the opportunity for attendance as far as possible and yet assure the obtaining of fit material for the student body.

The curriculum of the school should be of a far-reaching and thorough character and yet worked out so that a student could specialize in any one specific branch of welding. However, welding is an industry in which all classes are closely interwoven so that to be really proficient a man requires a sound working knowledge of all the various classes. Theory and actual practice should be logically arranged. In order to make the

*Paper presented before Annual Meeting, A. W. S., April, 1929.
†The Prairie Pipe Line Company, Tulsa, Okla.

school complete it should be so arranged as to permit a study of both the oxy-acetylene and arc processes as they may be properly applied to various phases of welding. While such a curriculum should be worked out and approved by a board of experts, may I briefly cover the matter for your reaction?

In the first place, equipment should be studied as to: (1) The purpose served by each unit of equipment; (2) instructions as to the internal working features of each unit; (3) the care of equipment; (4) the proper manner to set up equipment for various operations. In connection with equipment a brief summary could be given concerning the general and proper manner of handling oxygen and acetylene containers. If possible, various makes of standard equipment might be explained, not with a competitive idea or on a sales basis, which attitude should be avoided at all times. This would simply give the student a broad knowledge of all equipment so that he would be somewhat familiar with the major line of equipments when he reported for duty at some point where equipment was already installed. The presentation of such knowledge could be checked by regents or board before it was submitted to the school so as to regulate the nature of the matter, confining it strictly to an instructive basis.

Also a brief study of metallurgy should be introduced to cover the chemical and physical properties of various metals and their reaction to the welding flame. I find that some of the failures of certain present day constructions can be traced directly to the lack of knowledge on the part of the welder concerning the peculiarities of metals they were attempting to handle.

Welding materials such as oxygen, acetylene (compressed and generated), carbide, fluxes and welding rod, should be covered. This study to include the history of the origin of such materials in brief; the functioning of each material and the resultant mixing of gases in producing the welding flame as well as a somewhat special study of the selection of the proper size and grade of welding rod to select for certain constructions.

The subject of cutting should now be covered both as to theory and actual practice in the school laboratory on various kinds of metal. A brief history and explanation of the various devices or apparatus used in cutting should be considered.

Following cutting or in connection therewith comes welding. It might be divided into a study of: (1) Proper welding flame under various conditions; (2) theory and actual laboratory work in methods of or types of welding such as flat and ripple weld and their application to certain classes of construction; (3) theory and actual laboratory work on all classes of welding separated in proper order under subheads of the various classes such as wrought iron, cast iron, steel, aluminum, bronze, etc., with each of these individual class subheads divided into various modes of constructions under each such as, welding sheets and pipe, etc., under wrought iron; sheets, pipes and various castings under cast iron, and so on, until each class is thoroughly exhausted.

A study of construction details should be covered in a condensed form

to deal with drafting, blue print reading, study of layout work and the proper methods to follow in obtaining quick and accurate cutting and fitting.

A brief outline of business methods is important on matters such as methods of proper organization for various enterprises such as plant, welding shop, pipe line and general field work and methods of cost accumulation.

In connection with theoretical and laboratory work a regular series of lectures should be given both as a means of review of the various courses and to broaden the students conception of the industry at large. They could cover the origin of welding and its progress; modern applications; research; safety instructions, etc.

In connection with such a school a physical testing laboratory would be quite an asset. It could be used for proving various brands of workmanship produced by students and for research work of the student of ability. Such an installation would require quite an investment and if not practical, motion pictures and lectures showing physical tests on various fabrications from regular established research laboratories could be presented with desired effect. Even though the school might be equipped with a physical laboratory outside tests could be introduced in the above mentioned manner in connection with the lecture course. In a like manner chemical analysis could be explained. In fact, a theoretical explanation of chemical analysis is probably the most practical, for the student in such a school would not have a knowledge of chemistry and would not be concerned with the process of analysis of a chemical nature to the extent he would be toward a physical test.

All theoretical and laboratory work should be graded at regular intervals.

It will require the handling of experts to define the number of hours necessary for the average student to perfect the various stages of his welding course and a schedule arranged accordingly.

Some means might be devised to prevent a student from such a school from applying for a position under the name of the school when he has failed to grasp his work or left the school before he had reached a safe degree of perfection. Students who complete a regular course should be given a certificate accordingly.

This outline may appear rather elaborate when first presented, but I believe that with a proper condensation of all subjects and cutting of as much detail as possible a solid working schedule could be selected to render excellent results within a minimum time and still afford a mastering of the subject. As previously mentioned, this is matter for expert analysis but I believe that a student by proper application should complete the entire course in six months on a basis of thirty hours of classes per week. Thirty hours a week of actual class and laboratory work may appear to be a rather difficult schedule but I believe that the majority of students in such a school would be willing to spend such time in order to obtain a thorough course in as short a term as possible. Upon investigation it might be found that this schedule could be shortened as to

number of required hours of class per day and yet the result obtained within a six month's period.

When such schools are organized it would be well if corporations, large contractors and the like received word of same so that they might inform men whom they knew or had heard of being interested in obtaining such a course or even send men from their own organizations. At any rate, such schools should be advertised in some suitable manner.

In closing, permit me to state that I believe it would be best to found such a school within the engineering department of State universities, if possible. This would eventually lead to a general distribution of such schools throughout universities in various parts of the country. A certain number of hours in welding is already required in the majority of our present engineering schools of high standing, which touch upon the high points of this trade for students taking complete engineering courses. The facilities of departments already established might therefore be broadened to meet the additional requirements of a complete industrial welding course without so great an expense as would be required to establish an independent school. Of course, there is always the possibility that such a schooling could be established as a night trade school in connection with high-class high schools, for I understand that such opportunities are being provided to a greater extent each year. In such a case, however, the class work would be drawn over a longer period of time before completion for an average of ten hours per week would be about the limit for night school work, I believe. I do not think the night trade school would prove as satisfactory as the previously mentioned plan of incorporating the school within a university in a regular course.

In my opinion, the question is one worthy of much constructive thought and discussion. It should be solved and the opportunity opened whereby such schools be available for the benefit of industry in general. The American Welding Society should be the first in presenting a definite plan to bring about results in establishing the industrial welding school.

Organization and Management of an Industrial Welding School*

F. E. SELLMAN†

ELECTROLUX, the gas fired refrigerator when first placed in production offered some very interesting problems to the Manufacturing Division of the Company. The development models as well as the first sample units sent out to the Gas Public Utilities were, of course, built in the New York Laboratory and were the handiwork of expert welders.

The refrigerating unit consists primarily of three steel cylinders, inter-connected by steel tubes. The tubing welded ranges from 5/16 in. to 3¾ in. and the lineal welded distance is about 133 in. per unit. There

*Paper presented before Annual Meeting, A. W. S., April, 1929.
†Consulting Engineer, Servel, Inc., New York, N. Y.

are 53 welds, 14 connections which might be termed tack welds and 7 brazed connections making a total of 74 welds in all. The regular welded joint must be tight at 900 lb. air pressure. Oxy-acetylene is used throughout.

Late in 1926 it was decided to commence production of this type of refrigerating unit and the Newburgh, New York, factory was the place designated for this work. The little town of Newburgh had but few welders, and the half dozen there were all engaged in automobile repair work. Even with the conservative program of ten refrigerating units per day, meant a factory set-up of 740 welds per day. To do this work required welders of the most experienced type that could be secured. As stated above, these welders could not be secured locally but had to be imported. It was, therefore, necessary to advertise extensively and to secure them from different sections throughout the East. It was soon found that regardless of how much experience a man had had in welding that it was imperative to train the workmen for our own particular kind of work. Most of the welders hired could produce a neat appearing weld but the welds were found usually to be unsatisfactory, in that the welds would leak when subjected to our high air pressure tests.

Experience taught us that even though we hired experienced welders, additional training was necessary. Experienced welders were set in their ways and resented being taught new ways so the final policy was taking green men and training them in our own methods. This required the establishment of a welding school and with the able assistance of expert instructors from one of the large oxy-acetylene companies, the school soon turned out welders that could be used on sub-assembly work In connection with the training of students, it was decided to try out young women on the lighter and more intricate parts. The results obtained were very satisfactory and we soon found that for certain classes of work, the women welders after their training period, were able to turn out neater work than the men welders. This was particularly true on work that required a great deal of patience.

The work required of these welders might be termed difficult welding, for the Electrolux unit is almost entirely made up of seamless drawn tubing of from 11 to 17 BW gauge. The tubing is coiled and bent into various shapes and in some cases, the weld to be made is where a light thin section of pipe joins up with a heavy large section. This type of welding, of course, requires the operator to be very cautions about burning through the thin section and at the same time be sure that he has made a firm welded joint through the heavy section. Should any of the molten metal be forced through the thin tubing it would either totally or partially clog up the opening, rendering the machine inefficient or totally inoperative.

This point must be very carefully watched at the time the weld is made for should a unit get through to the final assembly with one plugged-up weld, it would be practically impossible to determine which one of the 53 welds is defective. On the other hand, should a unit not have a tight joint, a leak would show up in the high pressure air test making it necessary to again go over the weld. Extra repairing is not desired as it opens up the possibility of plugging inside of the tubing. It was there-

fore necessary that the welders on Electrolux units be capable of producing a tight welded joint the first time and one that would in addition to being leakproof, be sure of not being burned through.

Another point that has to be watched very carefully by the operator, is that he must be very careful about splattering metal inside the machine or heating the work to a point where scale would form on the inside of the pipe. To overcome these difficulties, the students were taught to bridge over the weld rather than to get extreme deep penetration.

The original set-up was to manufacture ten units per day. However, as soon as the sample models arrived in the field, the Public Service Utilities immediately started to swamp the company with orders. Production was stepped-up gradually from ten units per day to one hundred and twenty per day, which meant from 740 welds to 8880 welds per day. This step-up in production was entirely dependent on the rapidity with which students could be turned out from the Welding Schools.

At this time, it may be interesting to trace the method of instruction employed in the training of the welders for our work. The first step in the training of students was to teach them how to adjust the torch and to keep a neutral flame. The very ABC's of welding had to be used so the first welding operation was to run a bead on a piece of scrap sheet metal. Even during this preliminary period some of the students would be "washed out," as showing no inclination or adaptability for this line of work. This early state of the students' training was carefully watched so as to eliminate spending time and money on dead material. The second stage in the students' training was the welding together of flat pieces of scrap sheet steel. These pieces were from 3/32 in. to ⅛ in. in the thickness which corresponds to the thickness used in the steel in the Electrolux unit. The third operation in the students' training was the welding together of sheet pieces of scrap tubing. The students were taught to weld these short pieces of tubing together, the tubing being in various shapes. In all this work, the instructor endeavored to accustom the students to make the weld as near as possible identical to the welds made on the unit. This preliminary training was carefully watched by the instructors as it was necessary to teach the students the art of making a weld that would withstand a rigid inspection for leaks at 900 lb. air pressure. This was the most difficult part for the student welders, as they seemed to easily learn the art of making a neat job but the beginner generally failed, when it came to producing a welded joint that would not leak.

The above mentioned period of instruction in the Welding School averaged from three to six weeks, depending upon how quickly the student grasped the fundamentals of welding. The percentage of students who actually arrived at the point where they could go on production averaged about 50 per cent. The reason for the student's failure might be summed up as follows:

1. Lack of interest and attention.
2. Not liking the class of work.
3. Slow improvement thereby making it too costly to complete the instruction.

After the students had passed through the preliminary training of from three to six weeks, they were placed on the most non-essential productive jobs. Here they were as well closely supervised by the instructors and foremen until the percentage in leaks from their welding had dropped to practically nothing. Special high pressure air test fixtures were set up throughout the entire Welding Department so that their work could be quickly and readily checked and the attention of the welders immediately called to leaky welds. Leaky welds had to be repaired at no extra compensation to their regular piece-work rate. This fact brought on a further improvement in workmanship as every welder who had a tendency of slighting his work soon found it unprofitable to make repairs at his own expense.

Within a short time there were on the payrolls over one hundred men and women who had been taught to weld at our own school.

Due to the reorganization of the company, the Electrolux Department at Newburgh was transferred to Evansville, Indiana. This resulted in the same problems that had been experienced at Newburgh. Evansville, though larger in population, could practically boast of no more welders than Newburgh so it was necessary to again establish schools and go through the same procedure as had taken place at Newburgh. Practice makes perfect, and experience gained in developing welders from green hands stood the organization in good stead when they attempted the same work at Evansville.

Due to local conditions, the supply of girls at Evansville far exceeded that in Newburgh. The girls in Evansville were used to factory operation and in a short time developed into very fair welders. By this time, the demand for our refrigerators had increased so rapidly that the new school developed at Evansville had to prepare welders for a program of 250 units per day, which meant 2750 ft. of welding daily.

The students in the new school were placed in some buildings which had been set aside for this purpose. The school was arranged to handle 50 welders on each shift. The women welders were instructed on the daylight shift, while the male welders were instructed on the night shift, making it possible to have 100 students in the school at all times. This school was presided over by five of the Linde Air Products expert instructors. The method of instruction was carried out on practically the same lines as those previously mentioned in connection with the Newburgh school, and except that as a further inducement to the student, as soon as he graduated from the school, he was placed on productive work at a slightly advanced rate, and, as his skill increased, the rates were advanced in steps in keeping with his ability.

The equipment used at Evansville for this welding is—One Generator that has a capacity of 3000 cu. ft. and a Storage Tank Holder of 2000 ft. This equipment now supplies a total of 184 welding stations. The gas is piped throughout the entire Electrolux Division, as the plant layout of this division is on the progressive production system. We have standardized one make of torch that we have found best suited for our work and the size of Welding Tips range from a No. 2 to a No. 6, with a No. 5 tip the most frequently used.

As stated before, the entire Electrolux Division is laid out on a progressive production basis. All rough stock, which consists mostly of tubing, is received in carload lots and unloaded and stored in one end of the plant. Here also is located the machinery which cuts the tubing to specifications. After the cutting operations these parts are formed on special fixtures and machinery. The necessary holes are then drilled and all burrs carefully removed. The next operation is the washing out of all these parts, special care being required to see that they are thoroughly cleansed before welding. The tubing is placed in large metal baskets and the baskets agitated through boiling, hot, cleaning solution so that all grease and dirt are removed. As a further caution against dirt, the parts are then blown out by a high pressure live steam. The parts then proceed to the sub-assembly welding lines where the lighter and more delicate operations are handled by women welders.

After the fabrication of the evaporator, gas heat exchanger and absorber, the unit is thoroughly tested for air leaks at 900 pounds pressure. Only the most high grade and thoroughly trained men are allowed to do this work. This air test consists of connecting a high pressure air hose to the charging valve of the unit and the pressure turned on until the maximum pressure has been reached. All welding joints are then covered with a film of soap suds and thoroughly checked for leaks. This operation is repeated three times in order to detect the most minute leaks.

After the unit has passed the air test, it is then taken to the galvanizing room, where it is pickled for several hours, thoroughly scrubbed clean, dried and placed in the galvanizing bath. Only that portion of the unit which is placed within the refrigerator proper is galvanized. The absorber is given a heavy coat of tin.

From here the assembly goes to the final welding operation, at which time the generator, liquid heat exchanger, condenser and rectifier parts are added. The preliminary welding together with the sub-assemblies just mentioned are made adjacent to the main production line on which the main body of the unit has traveled. This eliminates all undue trucking of material used in connection with the welding of these assemblies. These sub-assemblies made by girls are, as fast as they are finished and inspected, passed across the bench to the men who are doing the final welding operation of the unit. The final welding operation of the machine completed, the welded joints are again tested for high pressure leaks. After this operation, it is placed into the metal case and is now ready for charging with ammonia and hydrogen, after which it is placed on special test racks and connected up to artificial gas and city water, where it undergoes a capacity cold test. During this cold test period inspectors make charts of the unit's performance and if the machine comes up to the rigid high standards set, it is passed and the chart filed away for future reference.

The cold testing operation completed, the metal case of the unit is completely filled with insulating material and sealed. The accessories, such as gas burner, gas thermostat, thermostatic water control, chilliator casting, are then attached, and, after another inspection, the Electrolux unit is ready to be mounted in the refrigerator box.

At the present moment the factory set up calls for 400 Electrolux units as a daily production. This means 29,600 welds or 4433 lineal feet of welding.

Additional welding operations occur in the Liner Department, where the liner seams are welded together. The flues through which the products of combustion passes are made of ascoloy steel and the caps on these flues are also welded.

In other departments throughout the shop where automobile truck bodies are assembled and in the Gas Engine Department, oxy-acetylene welding plays an important part. This other welding, of course, is but a minor operation as compared to the Electrolux Gas Refrigerator unit welding of today.

Organizing and Operating an Industrial Welding School*

C. E. CONWAY†

IN organizing and operating an industrial welding school the following factors must be given careful consideration:

1. Location.
2. Equipment.
3. Insurance.
4. Instructors.
5. Course Content.
6. Contacts with the Trade.
7. Advertising.
8. Enrolling Students.
9. Size of Class.
10. Supervision.
11. Reviews.
12. Grading.
13. Additional Instruction.
14. Preparation for License Examination.
15. Assistance in Locating Position.

1. *Location*—Possibly one of the best locations in the United States for a welding school is Manhattan, as the school would be within easy commuting distance for two million men. Many students who have to come from a distance to take a welding course prefer Manhattan on account of the many interesting sights which await the students' leisure hours and the great variety of amusement which the city affords. The large number of firms in and near Greater New York who employ welders is another argument in favor of selecting Manhattan, as these firms afford a possible chance of placement for the graduates of the school.

2. *Equipment*—The school should be equipped so that each student has the use of a welding torch throughout each minute of the duration of the course. There should be one or two extra torches available as reserve equipment. It is desirable for the school to standardize on one make of torch and gages, as this greatly facilitates repairs. If manifolds are used to supply gas to the torches these manifolds should be made of extra heavy pipe of small diameter in order to minimize danger. The installation should comply with all Fire Department

*Paper presented at Annual Meeting, A. W. S., April 24, 1929.

†Educational Director, Bedford Branch, Young Men's Christian Association, Brooklyn, N. Y.

regulations, including fireproof construction of shop, fire doors, special metal cabinet for acetylene tanks with vent to outside of building, etc.

3. *Insurance*—The school should be covered with adequate liability and property damage insurance.

4. *Instructors*—The instructors should be men of long practical experience in the welding field. Their appearance should be such as to command the respect of the students and they should be able to impart their knowledge in a pleasing and interesting manner. They should be level-headed and cool in the face of danger and patient with such students as do not readily acquire skill.

5. *Course Content*—This is possibly the most difficult factor to properly determine in organizing a welding school. The course a school should give would contain so many hours of theory and practical work that the price of the course would be prohibitive to 95 per cent of the men now enrolled in the welding schools of this country. The average man who enrolls for a welding course has very little money and as a rule he is willing to devote only a limited amount of time for his training. Many welding students have very little education and would become greatly discouraged if much theory were given. Not a few enroll for a welding course as the result of a small flare of ambition and they have not the stamina to carry through to the end of a course of proper length. Deciding upon the course content, therefore, becomes largely a matter of compromise between what the school authorities would like to give and what they have to give on account of the type of men with whom they have to deal.

6. *Contacts with the Trade*—It is highly desirable that the school authorities keep in close contact with the manufacturers of welding equipment, oxygen and acetylene gas, and also with the firms who employ welders. In this way the school receives many valuable suggestions and the students benefit by short lectures from time to time by the outstanding men of these organizations.

7. *Advertising*—If the school handles its own advertising, it should be continually experimenting to locate new mediums. For a school located in Manhattan the Male Instruction Column of the New York *Morning World* and the New York *American* bring results. If money is also available for some national advertising a medium like "Popular Mechanics" is good. A more or less hit and miss distribution of inexpensive folders through the mail and by other means produces students.

8. *Enrolling Students*—When, as a result of newspaper and other advertising, men come to the school to inquire about the course, they should be given courteous attention and should be shown through the welding school. Time enough should be given to each prospect to answer all questions he may desire to ask. When the man enrolls he should sign a definite contract with the school.

9. *Size of Class*—Each welding class should be limited to twelve students per instructor. This is necessary if the instructor is to give

each student the individual personal attention required for the student to make fair progress in acquiring skill at welding.

10. *Supervision*—The instructor should be with his class 100 per cent of the time the class is in session and the instructor should not have any duty to perform during that time excepting to instruct his class.

11. *Reviews*—Fifteen or 20 minutes should be spent in reviewing preceding lessons every third time the students come for instruction.

12. *Grading*—At the completion of the course each student should be graded according to the quality of his work and this grade should be put on enrollment card as a permanent record of that student's work.

13. *Additional Instruction*—When a student arrives at the end of the regular number of hours of instruction allotted to the course and has not acquired sufficient skill to hold a job, it is good policy for the school to give him additional instruction without additional charge.

14. *Preparation for License Examination*—During the course each student should be given definite instruction to prepare him to pass the license examination.

15. *Assistance in Locating Position*—No welding school should agree to find employment for every man who takes its welding course, since in placing its poor grade of students it quickly destroys all reputation with employers. If the school gets a call from an employer for a student and has no good material available at that time, the call should be passed up rather than send out a student who may not give satisfaction. The school should stand ready at all times to give what assistance it can in placing its men who have shown evidences of ability and industry, but the school should remember, its first duty is as a training agency and not as an employment bureau.

The Bedford Y. M. C. A. of Brooklyn has been giving instruction in oxy-acetylene welding since 1920 and in electric welding since 1927. The oxy-acetylene welding equipment now consists of fourteen torches for general work, six torches for airplane work, and one cutting torch. These torches are installed in two shops. One shop is 18 ft. by 23 ft. and has fourteen torches for general and airplane welding. The other shop is 20 ft. by 40 ft. and is equipped with six torches for actual fuselage building and repair. The cutting torch is part of a portable welding outfit. This is for convenience in cutting up auto chassis given us by auto wreckers for student welding practice. Both shops are fed with oxygen and acetylene from three acetylene tanks and one oxygen tank. The three acetylene tanks are connected by a header made of ⅛-in. steel pipe, feeding into manifolds of ½-in. extra heavy wrought iron pipe. The oxygen tank feeds into a manifold of ½-in. extra heavy wrought iron pipe. All torches in both shops are taken from these manifolds. During the fiscal year ending March 31, 1929, thirty-six students took electric welding, ninety-eight took general oxy-acetylene welding, twelve students took pipe oxy-acetylene welding, thirty-nine students took aviation oxy-acetylene welding, sixty-nine aviation mechanic students took aviation oxy-acetylene welding, and 154 auto mechanic students took auto oxy-acetylene welding, thus mak-

ing a total of 408 students who received instruction in welding during one year.

To teach these men required 531 tanks of oxygen, or a total of 116,810 cu. ft. and 233 tanks of acetylene or 56,240 cu. ft.

The school is equipped to handle three electric welding students at one time.

Following is an outline of the oxy-acetylene welding course now given by the school:

Lesson No. 1

Explanation and operation of regulators and welding torch. Carbonizing, neutral and oxidizing flames and their effects on steel. Don'ts —Spot welding steel. Butt welding flat steel.

Lesson No. 2

Repeat Lesson No. 1.

Lesson No. 3

Ripple welding. Butt welding steel for strength and finish.

Lesson No. 4

Horizontal and vertical welds on steel and welding alloy steel.

Lesson No. 5

Building bosses and filling holes in steel. Fluxes: their use and advantage.

Lesson No. 6

Overhead welding on steel.

Lesson No. 7

Welding sheet metal.

Lesson No. 8

Brazing steel, brass and copper.

Lesson No. 9

Brazing steel, cast iron and various alloy metals.

Lesson No. 10

Welding cast iron.

Lesson No. 11

Welding cast iron. Effect of expansion and contraction and how overcome.

Lesson No. 12

Aluminum welding.

Lesson No. 13

Aluminum welding.

Lesson No. 14

Repairing various automobile parts with the torch and cutting of steel.

Welding in Aircraft*

HAROLD A. BACKUS†

THE designer of aircraft has a hard task always before him—a self-imposed one, to be sure, but none the less exacting in its requirements that he conceive and execute stronger and lighter structures. The sky is literally the limit in design work, and materials and processes must continually show decided improvements to keep up with the rising demands. It seems there is almost no limit to the ingenuity of man in airplane design, and there is naturally noticeable a division of thought which may amount to "schools" of practice or even fads. It will be noticed, for instance, that there is a distinct trend at present toward the use of monoplane structures for the newer commercial aircraft. Great as are the advantages of this type, there still remain special opportunities for the sesquiplane and biplane. I would make the point that no one scheme of construction is universally predominant. Applying this statement to methods of joining, we can correctly state that while welding may be of great and general value, it is not the best for all conditions. The other methods of fusion joining, such as brazing and soldering and the mechanical methods of pinning, riveting, bolting, crimping, etc., each have their places of supremacy. Welding, however, is now qualified to be called the "standard" method of joining because of the general use of welded steel construction for fuselages, landing gear, tail skid and lesser fittings and non-structural parts. It is important that we consider in detail the exact status of welding as a means of joining, and this I propose to do as an introduction to further discussion of the effect of welding on designs, the airplane materials suitable for welding, the strength of welded joints, the operation and inspection of welding, and the repair of welded structures.

Welding as a method of joining seems to have shown three distinct stages of development and application. First came the period when its supposed unreliability was a subject of hesitant skepticism, until actual service results in ships which impressed me as suffering from ingenious but inefficient design showed us that these structures would hang together marvellously. Next came a general acceptance of the value of welded steel construction, and it is now so extensively used throughout the typical airplane that I believe it has reached its peak values in this application. There is a danger that some may seek to use it too diversely and thereby create a "school" of design of welded construction parallel to that made by the Junkers and Ford ships in riveted construction. The old Greek motto of "Everything in moderation and moderation in everything" is still beautifully true, and we will develop our highest types of aircraft designs only when we are freed from the arbitrary

* Paper presented before New York Section, A. W. S. Meeting, Feb. 5, 1929.
† Head of the Materials Department of the Curtiss Aeroplane & Motor Co., Inc., Garden City, L. I.

adherence to single purpose programs of construction and admit that there is a best material, a best method of joining, a best shape, etc., which can be determined only by a detailed study of the individual part itself. This does not make for an inconsistent program if the assembly as well as the detail is properly engineered.

The third phase is now showing itself in the restriction of welding in the highest performance ships to fittings and heat treated parts required to carry the heaviest loads in the primary structure. Wing beams, landing gear and fuselage carry-through members are welded and heat treated, but the major portion of the fuselage, the tail surfaces and the wing ribs are of light aluminum alloys. This trend in design has resulted from higher requirements in the ratio of strength to weight, and with the restriction of welding to these most important members, often heat treated, there is added the necessity for greater efficiency and reliability in the joint and adjacent material. As a result, the designer must know more in detail the limitations which welding imposes on his use of the material and its heat treatment and also the effect of the material on the welding.

Effect on Design

Perhaps the outstanding characteristic of a welded joint is its rigidity. The continuity of material and the usual good "fairing" of joints achieves a simplicity of form and a directness of load transmissal which is admirable. In contrast to a riveted joint, the material present works in tension as well as in compression and, therefore, has a lower average intensity of stress as well as a more uniform distribution. I well remember the period about eight years ago when I was laying out the detail structural design of the engine nacelles for the Navy's Giant Boat, a 70,000 lb. triplane with nine Liberty engines. Welding was prohibited and it was a mind-racking experience to achieve an efficient "follow-through" for such huge loads in a bolted and riveted structure. Both tension and compression loads often had to be transmitted in from three to eight different directions through a common intersection at a joint. Now such fittings would be welded units, and the troubles would be in the shop in keeping them from cracking rather than on the layout board. Indeed, welding is such a wonderful convenience in this way that it sometimes makes for lazy engineering methods. The tendency often is to abandon the careful niceties of design found in the efficient riveted construction and to assume that, if separate pieces of metal can be brought into contact, an arrow and the magic word "weld" will do the rest in the shop. Every draftsman ought to have an intimate knowledge of the engineering properties of a welded joint and be given an object lesson in the abuse of his materials and the failure of his design which is possible through unwarranted use of welding. I hope to point out a few of the more important points which should always be kept in mind.

In the first place, what is it that makes a weld so open to criticism? Merely the fact that it is a bit of cast metal which has been deposited between, or melted from, two adjacent pieces of material, usually wrought and, therefore, of superior physical characteristics. This joint

represents a discontinuity of physical state in regard to strength, ductility, shock resistance and corrosion resistance; it is a region of burned metal which cannot be wholly restored by any heat treatment; and in its formation, it sets up unequal thermal stresses that often cause its ruin. All these defects are endured for the sake of convenience in design and manufacture, but they must be controlled and reduced to a minimum or the result is costly failure.

In order to create a physical bond, the surface oxides must first melt and then the surface metal itself become molten. The extent of this molten metal is indicated in Figure 1 by the dotted or salt-and-pepper regions. This burned or overheated metal in a weld causes all the troubles just enumerated because of two factors—first, it has low strength and elongation both at welding heat and when cooling; and second, it is a region at higher temperature than the surrounding metal and, therefore, subject to thermal stresses. It might seem that proper preheating would reduce these stresses to safe values and so eliminate most of the cracking experienced. This is not a practical solution for airplane fittings in conventional materials, because obviously the whole fitting cannot be brought to welding temperature and any extra heating causes warpage, scaling and reduces the strength of adjacent metal.

The solution to the vexing problem of cracked welded parts seems to be in the quick but skillful operation of the welder. The personal equation is the deciding factor. This is of the greatest importance to note, because it limits the expansion possibilities of welded design. The more one studies the vagaries of welded joints the less one trusts even the boss welder. Experienced welders are not hired nowadays when desired —they have to be trained and constantly checked, and the general demand for welders in aircraft leads anyone who has brazed an exhaust manifold or welded boiler plates to consider himself a welder. Such men have to be broken of their bad habits, and it is often easier to completely train a new man. This situation means that an increased production schedule is embarrassed by lack of properly trained men and is a factor in the decision to use riveted joints in duralumin where other conditions permit. The whole trend of aircraft design is toward the elimination of the extra factors of safety, imposed by ignorance of stress loadings and of the ability of the structure to withstand these loadings. Welding shares with cast materials the handicap of factors of ignorance which are not written into design in wrought material. The only way in sight to give a weld a rating of 100 per cent is to make a load test, but this is either impractical to apply or it results in distortion or destruction of the structure.

We are faced, therefore, with the knowledge that a weld at best is of unknown reliability and that to make it without cracking takes expert manipulation by an experienced welder—plus some luck. I may seem to over-emphasize this feature of unreliability, but we are dealing with the old case of the chain and the one weak link. The more refined the design the less the superfluous metal present to make up for deficiencies between assumed and actual performance and the nearer we are to a state where only positive uniformity and reliability can be safely

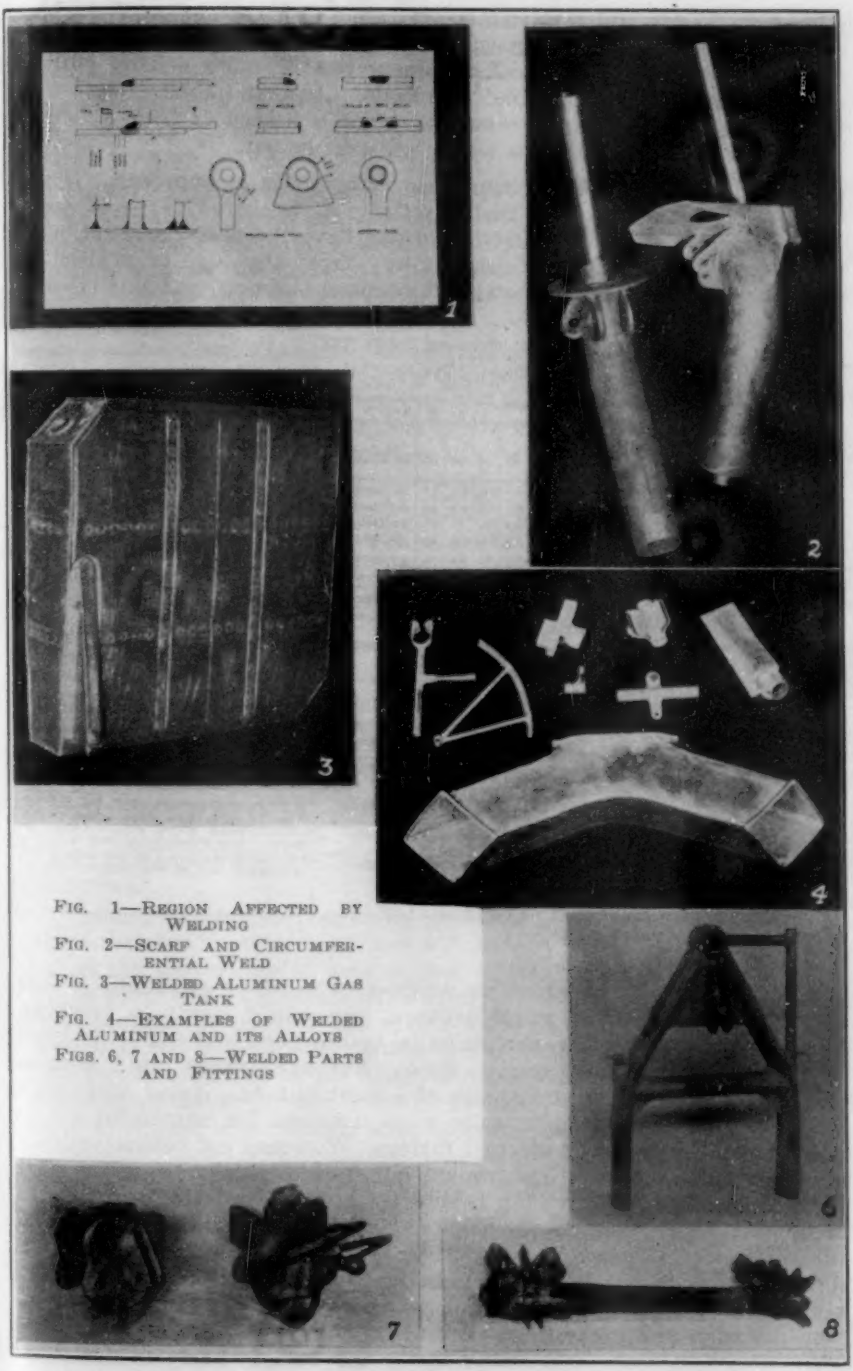


FIG. 1—REGION AFFECTED BY WELDING

FIG. 2—SCARF AND CIRCUMFERENTIAL WELD

FIG. 3—WELDED ALUMINUM GAS TANK

FIG. 4—EXAMPLES OF WELDED ALUMINUM AND ITS ALLOYS

FIGS. 6, 7 AND 8—WELDED PARTS AND FITTINGS

tolerated. Welds and cast metals are faced with the choice of working to arbitrarily reduced design values or of proving their fitness in each specimen by some load test, X-ray inspection or other equally positive check. It is this no man's land of unreliability that I shall explore with you, trying to learn those precautions which will keep us from stumbling into it and to find those paths which will take us out.

The morasse of cracked fittings has many paths of approach. If you will keep in mind the fact that a weld is a "puckered" area of metal which is trying to rupture itself, you will have the best visualization of the case. If the puckering occurs away from the edge of a sheet or tube, it is difficult for the metal to be broken through, and this class of

DESIGN VALUES - WELDED STEEL

SPECIFICATION	MATERIAL & FORM	SIZE	HEAT TREATMENT SPEC.	PHYSICAL PROPERTIES (THOUSANDS OF POUNDS PER SQUARE INCH) ULT. ITENS	YIELD POINT	SHEAR	BEARING			BRINELL (3000 KG)	IZOD'S FT. LBS.	REMARKS
							I	E	ER			
57-103	FORGINGS	ALL	NORMALIZE 90-100									
57-107-9	BAR		NORMAL OR NORMALIZE 90-100									
57-136-3	SHEET	ALL		55	36	35	90	60	22	55	28000	GENERAL USE, FITTINGS, MACHINED PARTS, CASE HARDENED PARTS, WELDED, BRAZED, SILVER SOLDERED HEAT TREATED WITH ALLOY STEELS, NORMALIZED OR "AS RECEIVED"
57-180-1A	TUBE											
4130	FORGINGS			100	80	65	140	95	35	100	29000	ROCKWELL STANDARD PROPERTIES OF HEAT TREATED STEELS. C16-C25 HEAT TREATED BUT NOT WELDED
57-107-19	BAR & FORGINGS			125	105	80	175	115	44	125	29000	C20-C30 MAY BE BRAZED & THEN HEAT TREATED
				150	125	100	190	125	47	150	29000	C24-C30 SEE NOTES ④ & ⑤.
				180	140	115	200	135	50	180	29000	C34-C46
57-136-6	4130	SHEET		(90-100) 90	60	50	125	85	31	80	29000	ALLOY STEEL MAY BE WELDED WHEN WELDED & THEN HEAT TREATED. AFTER WELDING MAY BE BRAZED & THEN HEAT TREATED. PARTICULARLY FAVORED ARE FOR STANDARD HEAT TREATMENT, T.S & ROCKWELL VALUES TO BE SPECIFIED AS ABOVE. SEE NOTES ③, ④ & ⑥
5-206	4130	BAR		(90-100) 90	64	64	140	95	35	100	29000	
5-205	4130	SHEET	ALL	(110-120) 110	100	80	150	100	37	120	29000	
57-180-2A	4130	TUBE (ROUND)		(130-140) 130	115	92	160	105	40	144	29000	
57-183	4130	TUBE (STREAMLINE)		80	60	50	125	85	31	80	29000	ALLOY STEEL MAY BE WELDED OR BRAZED WHEN HEAT TREATED & THEN WELDED OR BRAZED. STANDARD HEAT TREATMENT, T.S & ROCKWELL VALUES AS ABOVE ARE TO BE SPECIFIED. SEE NOTES ②, ④ & ⑥.
				50		50	90					DEPOSITED WELD METAL CALCULATED ON AREA OF ORIGINAL MATERIAL ADJACENT TO WELD. SEE NOTE ③
57-176-8	4130	SHEET	ALL	NONE	65	45	40	110	75	27	65	29000
57-107-19	4130	BAR	<1½									AS SUPPLIED FROM MILLS WITHOUT FURTHER HEAT TREATMENT & MAY BE WELDED, BRAZED OR SILVER SOLDERED. SEE NOTE ①.
57-107-19	4130	BAR	>1½	NONE	55	36	35	80	60	22	55	28000
57-180-2A	4130	TUBE (ROUND)	ALL & NOT WELDED	NONE	55							
57-180-2A	4130	TUBE (ROUND)	WELDED		85	60	60	140	95	35	98	29000	AS SUPPLIED FROM MILLS WITHOUT FURTHER HEAT TREATMENT.
5-206	4130	BAR	ALL	NONE (ROCKWELL STANDARD FOR 5-205 & 5-206 ONLY)	80	60	50	125	85	31	80	29000	AS TO MAY BE WELDING BRAZING OR SILVER SOLDERING OR LOCALLY HEATED FOR SILVER SOLDERING WITHOUT FURTHER HEAT TREATMENT WITH STRESSES AT JOINT, SEE NOTE ③ & ⑥
5-205	4130	SHEET										
57-183	4130	TUBE (STREAMLINE)			60	60	50	125	85	31	80	29000	TUBE MAY BE WELDING, BRAZING OR SILVER SOLDERING WITH 75 PERCENT AT JOINT. SEE NOTES ③ & ⑥ OR EXCEPTIONS
5-207	4130 STAINLESS STEEL	SHEET										
5-208	4130 STAINLESS STEEL	BAR										
5-215	4130 STAINLESS STEEL	TUBE										

FIG. 5

failure is not too frequent. Two welds close together, especially if they leave a thin section of metal between, can easily result in cracking, because there is a double shrinkage to be absorbed and but little space in which the stretching can be done. But most welds crack because this "puckering" occurs at the edge of a sheet or tube. *Avoid edge welds.* This is literally and emphatically a requirement for successful design and production of welded aircraft fittings. You may not believe yourself guilty of contribution to this trouble, but study carefully the accompanying illustrations and see how frequently opportunities for such cracks occur. Tack welding on the edges is fruitful of cracks. Sheet and tube both have a "grain," and splitting is easier in one direction because the transverse strength or elongation are relatively lower. The edge welding of washers provides a place where the weld metal climbs up over the edge and goes off on the flat surface of the sheet. This place where the bare plate first shows under the weld is likely to develop a

crack, and so welding must be eliminated here. The alternate design shown at the lower right in Figure 1 uses an inserted tube instead of one or two washers as reinforcements for a lug in bearing. This prevents the metal across the neck of the lug from being subjected to welding and so keeps all its strength and ductility, which is of special importance where heat treated steel is used.

"Puckering" further depends on the proportion of the total thickness of metal reduced to the molten conditions. Consequently, welding performed on both sides of a sheet metal joint is doubly provocative of trouble—and is often unnecessary from a strength point of view. Gusset plates of 0.050 and thinner metal should be welded on one side only, and this one weld should be generous and well executed. The welder should always weld toward an edge—never starting at the edge and working inward. The former practice prevents initial overheating and burning the edge before the rest of the metal is heated to the welding temperature. Welding should also be done away from a heavy section for the same reason. The direction of weld is easily checked by observing the overlaid scallops of weld metal which are made in the same order that shingles are laid.

Welds which go all around a tube are very undesirable in such highly stressed members as landing gear and control members. Not only does welding decrease the tensile strength of the extreme fibers in bending, but it seriously affects the shock resistance of the whole assembly. Tests on material cut from an axle which had been subjected to the heat of welding showed that the original material of the axle had suffered a 10 per cent decrease in ultimate strength and a 75 per cent decrease in elongation. This means that the static strength in bending was only 90 per cent of the original strength and the energy absorbing power of the material, which might be sorely needed in a crash, was only 22 per cent of its former value. A ring weld under these conditions should be prohibited, but it is often used. Slightly better conditions are met in Figure 2 where a scarf weld and an incomplete circumferential weld are illustrated.

"Tension" welds are frequently prohibited, but there are many cases where the classification as a "tension" or as a "shear" weld is arbitrary. Let us say that a line of weld normal to the applied tensile stress shall not be permitted in primary structures. This gives a chance for shear components to be resolved and allows us to commend all scarf, "V," and some hole welds as adding to the linear length of weld under stress. This lengthening out of the weld is important, as we have only a low carbon cast metal in this joint to transmit loads between alloy steel parts which are often heat treated to two, three and four times its unit strength.

Holes which are filled with weld are a delusion. They average a high percentage of "duds" because the welder only thinks he has fused the joint, while instead he has only puddled in a little weld metal. If the diameter is kept large enough to make it a case of a circular line weld, there is a chance for success, and not otherwise.

But welding has its advantages for the designer. The convenience with which castings and forgings may be duplicated in function, in strength,

in weight, and almost in detail dimensions, allows the speedy experimental construction of parts which are intended to be castings or forgings in production. Bar, sheet and tube pieces go together in amazing shapes that bear witness to my repeated contention that we are still suffering from "inventional" design when the soul of the shop man is aching for "production" design. I admit aircraft design is in a transition state, but let us never forget that it is easier to erase a pencil line once than to cut many thicknesses of steel.

The same scheme of design which made welded steel tubular fuselages so popular has been extended to the development of wing beams. The erection of large vertical heat treatment furnaces has made possible the heat treatment of these beams after welding as easily as the heat treatment of the individual tubes was formerly accomplished before welding. Both types of construction are feasible and have so far proven to be the strongest for a given weight. This application is quite consistent with the trend which makes the most heavily loaded members of welded and heat treated steel, leaving the less highly stressed members for fabrication of duralumin or other aluminum alloy. Welding has here proven of great advantage for it makes possible a very efficient beam design that is simple to build in metal.

Another new development in aircraft welding is the spot welding of many ferrous and aluminum alloys. Much experimentation remains to be done, but the process is showing unmistakable signs of being a companion process to line welding and riveting. The latter process is frequently being replaced by spot welding, particularly in steel, where the advantages of economy in material and time are considerable. The industrial world has speedily adopted this process, but the aeronautic fraternity have so far been dubious as to the efficiency and reliability of the spot welds. Their demands are much more difficult to meet in this regard, but a scientific understanding of the causes of trouble will bring final success in this field. The Aluminum Company of America has done some very commendable research on the spot welding of aluminum and its alloys and the following quotation from Mr. Dunlap's recent article in "Aviation" is very illuminating. "Most metals are most easily welded when in the stage of plasticity lying between the molten and solid states, hence those metals which remain plastic the longest while cooling are the easiest to weld, and vice versa. In order to be welded, the metal must tend to flow at some critical temperature, so that it will cohere when pressure is applied. Aluminum is one of the few metals that does not become plastic until its melting temperatures are closely approached. Therefore, welding conditions must be very closely controlled. Aluminum must be welded almost instantly in order to secure the desired kind of welded point. The reason for this is that oxidation takes place if the heating is applied over any appreciable length of time. By making aluminum welds practically instantaneous, the weld is consummated without time for oxidation. In fact, the quicker any kind of weld is made in any metal the better and stronger the weld is likely to be."

Materials Suitable for Welding.

The aluminum alloy group has but recently been considered available for welding. Perhaps the most satisfactory examples are those which

have been worked in aluminum. Engine cowling is usually made from welded sheet aluminum with the welds hammered so as to increase both their ductility and their appearance. Water connections and gas and oil tanks are other favorites to which welded aluminum construction is successfully applied. Figure 3 illustrates a welded aluminum gas tank which shows the principal features of construction which have been found necessary.

You will notice the presence of expansion bends in the shell which are necessary to provide relief for the shrinkage stresses set up at each weld. The rivet heads, filler neck, drain holes and seams are all welded with pure aluminum welding rod and an oxyacetylene flame.

The principal strong alloys of aluminum (duralumin, alclad and 51S and 25S metals) are capable of being easily welded with 4½ per cent silicon welding wire and the oxyhydrogen flame. This special welding rod is necessary because its melting point is lower than that of the alloys to be welded, and the oxyhydrogen flame is used because it is cleaner and not so hot as the oxyacetylene. Examples of welded aluminum and aluminum alloys are shown in figure 4. A very interesting and practical application of welding is in the new styles of furniture manufactured by the Aluminum Company from their 51S material, a silicon aluminum alloy. The ferrous alloys which are ordinarily welded in aircraft construction are in the carbon steel and chromium steel groups. Large quantities of S.A.E. 1015, 1020 and 1025 bar, sheet and tubing have been used and still find very extensive application. While carbon steel tubing for fuselages is gradually being replaced by the stronger chrome molybdenum steel we find that both seamless and welded carbon steel tubes are holding their own for the long interplane streamline struts, where the modulus of elasticity is the determining strength factor rather than the ultimate tension stress of the material.

Chrome vanadium steel with a carbon content between .20 and .40 was formerly used as the standard structural material for high strength parts and also for those parts which needed to be welded. There has been a wholesale change lately to the chrome molybdenum analysis corresponding to S.A.E. X4130, because of the very desirable advantage. which the higher percentage of chromium gave through the strength developed by air hardening from normalizing or welding temperatures. The use of this material in bar, sheet and tube form has made it possible to raise the basis standard of design strength which was formerly set for carbon steels at 55,000 lb. per sq. in. to a value of 95,000 lb. per sq. in., a value which could be developed by normalizing and which would not be lowered by the subsequent operation of welding into an assembly such as a fitting or a fuselage. Advantage can often be taken of the automatic air hardening properties of X4130 steel for making washers of this material and counting on the heat of welding to raise them wholly above the temperature needed for this hardening. Washers blanked from annealed sheet thus become heat treated to 95,000 lb. T. S. by the mere act of welding in position.

The chart shown in figure 5 illustrates the types of steels which are standard with the Curtiss Company and which are representative of the steels used throughout the aircraft industry. The materials referred

to a specifications S-205 and S-206 are S.A.E. X4130 material purchased to a physical specification of 95,000 lb. T. S.

Specifications S-207, S-208 and S-215 refer to austenitic stainless steel of the 8 per cent nickel—18 per cent chromium analysis represented by Allegheny metal and other brands. This analysis of stainless steel is most suitable for welding, as the austenitic character of the metal prevents to a large extent the formation during welding of the coarse brittle structure so easily developed in the other grades of stainless steel with their high alloy content. This type of steel is the subject of very active research work on the part of many of the steel makers and we may expect to learn shortly of variations in this type which will be still more interesting and valuable for special applications. In welding this material it seems necessary to give a single quick pass of the torch, melting only enough of the surface to make for good adhesion of the weld. It is easily welded in the thicker sizes by the electric process, which, however, has an inherent disadvantage in the excessive heat of the arc. It is not considered wise to electrically weld steel less than 0.063 in thickness at the present time, but more experience may permit us to attempt work with the oxyacetylene flame on 0.022 metal, which is the limit now in welding chrome molybdenum steel.

The welding of nickel and other alloy steels is not to be recommended because these not only fail to develop after welding the high strength of the chrome molybdenum steel, but they are much more susceptible to grain growth and its resulting brittleness. It seems a particularly convenient, but nevertheless very dangerous practice to weld the standard type of heat treated nickel steel bolt into some fitting or clip by which it is held in position. Four instances of complete and speedy failures of the bolt in such cases have come to my personal attention and I am certain there are enough more cases to warrant a general warning of this misapplication of welding.

Welding is also used for depositing materials which in themselves are hard, wear resistant and corrosion resistant. The best known of these materials is Stellite which is frequently deposited on tail skid shoes to increase the life of these severely abused members. Low carbon steel weld metal is sometimes deposited on cast manganese steel tail skid shoes to form lugs or inserts which are capable of being machined more readily than the manganese steel.

Strength of welded materials

The chart given in figure 5 also gives the design strength values which are used by the Curtiss Company under the conditions and with the materials noted. The physical properties given are not necessarily those which the material develops in the condition indicated, but are sometimes arbitrarily fixed. These are *maximum* values set for design purposes only, and are not to be confused with the minimum test values of the specifications to which the materials are purchased and inspected.

The following notes apply to references given in this chart.

(3) "In the design of welded specification 57-180-2A and 57-183 steel tube fuselages, wing spar trusses, compression ribs, and similar members, the average tensile stress in tubes entering joints at which

more than six members converge shall not be greater than 60,000 lb./sq. in. unless the joint is reinforced in a satisfactory manner. In this connection, a tube that is continuous through the joint will be counted as two members. Every case in which such a joint is reinforced and designed to carry a higher stress than 60,000 lb./sq. in. must be covered by specific authority."

(4) "These unit stresses are to be used only for the heated areas adjacent to the welded or brazed portions and each case must be considered on its own merits. In locations not affected by the heat of welding or brazing the values given for heat treated steel may be used."

(5) "The strength of a welded joint is usually that of the annealed material of the parts welded. When tested to failure, breakage in unheat treated materials will usually occur at the edge of the area affected by the welding heat, not at the joint. Welded alloy steel parts should be heat treated whenever possible, not only to secure the high strength possible, but also to remove cooling strains and overheated spots. Burned metal cannot be restored, however."

The reduction on welding of duralumin and other strong aluminum alloys amounts to about 50 per cent. This loss can not be recovered by heat treatment since the material is left in the cast state and these strong alloys must be not only heat treated but mechanically worked to secure the high physical properties with which we are now so familiar.

The material of the deposited weld metal has, of course, a serious influence on the strength of the joint. The usual material is low carbon steel, relatively much freer from impurities than the various steels with which it is united. The values for the design strength of joints of this material are given in the table. It is, of course, possible to use strips or wire of the same analysis as the alloy steel to be welded, but this use is not general practice and I do not consider it generally advisable for aircraft work. It is true that with perfect welds, a strength approaching the strength of the original alloy steel itself may be secured. Tubes of chrome molybdenum steel welded with metal of the same composition and then heat treated to produce 150,000 lb. T.S. have repeatedly shown the weld itself to be capable of developing this same strength. The trouble is that with a few delightful tests showing more than 150,000 lb. T. S., there will be others in which the strength falls perhaps to 30,000 or 40,000 lb. T.S., a value which is lower than that of the normal low carbon welded joint. This factor of greater unreliability and the extra fussiness of the metal in welding have practically forced the discarding of alloy steel welding rods. The only common exception is in the stainless steel group, where the austenitic steels are as readily welded with strips of the same material as with the usual low carbon wire.

The chart also indicates a reduction in the design strength allowable for metal in the vicinity of a weld. It is estimated that such material suffers an average loss of strength of 20 per cent due to the presence of some burned metal of indefinite depth.

From these values it is interesting to note the difference in allow-

able strengths of the various parts of the two types of welded beams which have been mentioned before. The first type was made from tubes which had been individually heat treated to 125,000 T.S. and subsequently welded together into an assembly. The second type was first welded together using annealed steel tubing and was then heat treated as an assembly to 125,000 T. S. The major portion of each strut length between joints is at a nominal strength of 125,000 lb. per sq. in. in both cases. The metal immediately adjacent to the weld is, in the first case, arbitrarily restricted in the strength calculations to 80,000 lb. T. S., while in the second case it rises to an allowable 100,000 T. S. Since these values are minimum for the whole assembly, it follows that these are the limiting values for all tension stresses and the second example is thus 25 per cent stronger than the first. Since compression stresses are the determining one for certain members, however, we must in fairness remember that both cases have an effective strength in compression for long members of 125,000 lb. per sq. in. in the mid-section, where a high yield point is needed, even though the end regions have a lower allowable stress intensity.

Shop Operations

Attention has already been called to the subject of preheating before welding. For aircraft tube and sheet in various materials this is not usually advisable, although for casting repair it is genuinely necessary. It is of greater advantage to anneal or normalize or heat treat after welding because through this thermal treatment there is possible a relief of internal stresses and a refinement of the grain. With the general use of chrome molybdenum steels for welded parts, however, annealing is seldom resorted to, except as a preliminary to a further heat treatment, because of the reduction in strength below the 95,000 T. S. limit involved. Normalizing is performed on a very small percentage of fittings, but generally such parts require the greater tensile strength of a regular quench and draw heat treatment. Practically, therefore, welded steel aircraft parts are made of carbon or chrome molybdenum steel, are not preheated, and are either left "as welded" or are heat treated within the range of 125,000-180,000 T. S.

I shall not attempt to give information on the actual operation of welding. You are undoubtedly better qualified to instruct me on the subject, as in this phase I am the layman and you the experts. I cannot refrain from commenting, however, on the relative advantages of gas and electric welding from the point of view of the aircraft designer and constructor. Of the many companies, including my own, which have investigated electric welding for thin materials, only one has adopted it for production work, and then after considerable experimental work and the construction of specially designed apparatus. In a word, electric welding is too intense in its local heating on material less than 1/10 in. thick. On thin material the base metal is actually burned away if the operator is not very careful indeed, and if by good fortune this does not happen, the joint freely shows in its fracture the presence of excessively large grain structure. This is only an intensification of the defect always associated with welding and is,

therefore, a step in the wrong direction in constructions where it is so important that the structure of the metal be maintained in first class condition. On material thicker than 1/10 in. there seems to be enough of the section unaffected to keep the average strength and ductility for the whole section within tolerable limits. It is here that we can make good use of the outstanding advantages of electric welding, which are for us its (1) speed of working and (2) its handiness in recesses which are awkward to fill by gas welding. It is sometimes claimed that less experienced personnel can be used in electric welding than in gas welding. For us this is true if we limit electric welding to the manufacture of jigs and other accessories not actually involved in the primary structure of the ship itself. It seems to me that the time must come when some form of electric welding can be safely used in making such aircraft parts as may at that time be welded. I believe I can offer for research no more valuable subjects for our mutual advancement than the development of apparatus and methods for the electric welding of thin material for aircraft, and as a second item, the procedure control of all welding operations, both electric and gas.

Inspection of Welding

It is recognized already that the only successful way to increase the efficiency and reliability of welding in aircraft is to institute a campaign against every theoretical source of trouble. The periodic recurrences of welding difficulties have shown us that the problem is by no means under complete control. The situation has an analogy in the criminal affairs of this city. The general control is very good, but there are still enough criminals loose to play tag with the whole police department. It will take a general rounding up of all offenders and a permanent settlement of their cases to make us believe we have solved the problem. Just so with welding. We can campaign according to the schedule which is given below, but this will have only a temporary effect unless provision is made for continued adherence to those principles of workmanship, of design and of shop procedure which are therein found necessary and desirable.

A general survey was made at the Curtiss Garden City plant and the campaign was divided into three divisions, covering workmanship, design, and material.

Workmanship has to do with two main items. First, supervision, which covered the examination of applicants, the training of apprentices, the inspection of work in progress and the survey of rejected parts, and second, defective operations which included such points as degree of preheating, burning through on repeated or prolonged heating, lack of adhesion in the weld, incorrect welding flame, direction of welding, and general lack of skill on the part of the workman.

Under design, we split our attack on the three forms of material chiefly used; that is, bar, tube and sheet. Bar and forgings are practically free from trouble in regard to welding. Tubing suffers mostly from burning-through because of the relative thinness of the section, except where welded at a cut edge, when conditions are the same as for sheet stock. Sheet, particularly steel sheet, seems to give the most trouble with crack-

ing. As previously indicated, edge welds are most serious offenders and as each instance of trouble comes up for settlement, we keep in mind the following possible variations in design or operation which may remedy the trouble. (1) We may leave extra material at the edge and plan to trim this off later if cracking develops, or we can turn a tab of metal and weld only as far as the bend, thus avoiding welding to the very edge of the sheet. (2) We can reduce the amount of welding in the region of the edge of the sheet so as to prevent burning it even though it may not be welded. (3) We can weld only on one side of the sheet especially in the case of stiffening webs and for all stock 0.050. (4) We can eliminate the gobs of weld which the average workman seems to think improves the appearance of his product, but which only results in extra weight, more burned metal and more opportunities for cracking.

In the choice of materials we have another factor in the fight. Carbon steels below about 0.30 carbon are the easiest to weld and there are many places in even high performance ships where bulk and rigidity rather than unit strength are the deciding factors when this material can be used. The designer should always remember it is his duty to use a material or product as commercially convenient to procure and as easily workable as the design will permit without sacrifice of efficiency. Alloy steels are the most serious offenders so far as cracking is concerned and their use must be justified before the attendant difficulties of welding and fabrication are thrust upon the shop. Of the alloy steels, the now standard chrome molybdenum steel of thirty point carbon analysis is the most easily weldable, but other types should be used with restraint. There is a natural tendency to believe that aircraft need and merit the use of many special purpose materials, particularly steels. But I have noticed that when a designer has finished making the drawings and specifying the materials for a ship, that it is possible to review those designs and eliminate the greater part of what may be called non-standard materials without appreciable loss in performance or weight and with very considerable benefit in the ease of production.

To carry out the necessary program of correction and prevention the following procedure for shop construction is in effect in the Curtiss plant and I would most strongly urge that similar precautions be taken in all aircraft plants using welding.

(1) The inspection of important tack welded assemblies for placement of weld metal, for correct cut-away of nested pieces and for items influencing design which have been listed directly above. (Welding Inspector.) (2) Inspection of first piece completely welded to correct errors in workmanship, etc. Work should not progress on other pieces until "go ahead" is given on first piece. (Welding Inspector.) (3) Inspection of lot of completed parts. (Routine bench inspection as at present.) (4) Salvage inspection of welded parts. (To include welding inspector in addition to chief inspector, etc.) (5) Correction of drawings through project engineer and engineering orders. This includes changes necessary on drawings to correctly show or indicate the exact position of all weld metal. This placement of weld metal is difficult to check on the original drawing, but after the completion of the first article, the drawing should then be made a permanent record of the correct detail practice in welding. It is only by this record, which should be faithfully made,

that specific requirements for repetition manufacture of this part can be successfully carried on. (6) Periodic fracturing of welded samples. (7) Stamping of work with individual stamp by welder.

Items 6 and 7 are necessary routine provisions for keeping the work of the individual welder up to the standard which he has passed before being allowed to work on aircraft parts. This may seem an unnecessary nuisance to those shop men and engineers who are wholly production minded but there is actually so little real inspection that can be given to a completed weld, that any attention we can give to the attendant processes is hardly too much for aircraft work.

The welding inspector should have all the qualifications of a boss welder and should have at least the instincts of an engineer. He should be competent to instruct welders in the proper procedure of their work and should have authority to see that any necessary action is taken which may affect shop personnel or engineering features. It is important that he have direct contact with the workmen in order that engineering interests may not be defeated by the ignorance or arbitrariness of either the foreman or his workmen. In regard to the placement of weld metal and other features of distinctly engineering character, however, the welding inspector should have the authority of the project engineer on the job in regard to all changes, because this type of criticism is really a carry-through of engineering requirements into the shop of a kind which cannot be easily shown on the drawings themselves, and which must, therefore, be taken care of by personal contact at first.

Repair of Welded Structures

One of the advantages of welding as a method of joining is the ease with which additions or replacements may be made to a completed structure. This advantage maintains not only in the reconstruction of experimental designs but also in the field repair of damaged ships. There are certain parts, however, which should never be welded and other items on which rewelding is not to be recommended except under the supervision of the designing engineer. Such members as tie rods, cables and wires should never be welded because of their special composition and because their strength is secured in large part through cold working. Brazed or soldered parts are also excluded because the brazing or soldering mixture penetrates the hot steel and weakens it. In general heat treated parts will have their strength severely reduced by welding without further reheat treatment. Such work should be done in the field only as a matter of extreme emergency to permit a pilot to fly to another field suitably equipped for major repairs. Standard parts such as turnbuckles, bolts, tie rod clevises, clevis pins and other heat treated parts of nickel steel should not be welded.

In repairing tubular structures, the joints should be thoroughly cleaned by wire brushing and any necessary splices be made close to a strut point, using only fish tail splices. In the repair of fittings, it is often possible to reweld heat treated parts without decreasing their load carrying capacity by protecting the highly stressed regions from the heat of the welding flame by wet asbestos or cloths and by restricting the heating to gusset plates, strut sockets, or other very local regions of low

stress intensity. With chrome molybdenum steel the regions affected can still be counted on to develop about 95,000 T. S.

No welds should be made over a failure in an electric weld. The deposited metal and a portion of the original metal should be removed by chipping and the joint filled in with the oxyacetylene torch. Rewelding a weld which has been made with the oxyacetylene torch in the first place is less objectionable, but extra precaution should be taken to see that the trouble is not magnified rather than reduced by the repair itself.

With chrome molybdenum and carbon steels used in the unheat treated condition, the welding torch is a great convenience for the adjustment of bent lugs, and the normalizing action obtained through heat for bending is distinctly beneficial.

In conclusion, I would remind you that while welding is a process of great value in aircraft construction, it is only one of several methods of joining the structures and the degree to which it will be used in the future depends not only on the materials and the design but also upon the possibilities for increasing the general reliability of the welded product. Its application in aircraft is already wide spread, but before it can find new applications and before it should be more widely used in its present applications, correct procedure control of all operations should be made effective. I would also recall my statement regarding the need for development of electric welding, for I am sure you will all agree that there should be some most interesting applications of this art ahead of us.

High Pressure Distribution of Manufactured Gas by the Aid of Welded Pipe Lines*

By C. M. Hendry†

An important link in the gas transmission system now serving Long Island is an extension of approximately 16 miles of 12-in. welded steel main recently completed between Lakeview and Farmingdale.

The route of this installation included the extremes in conditions encountered from open country and swamps to the passage through such communities as Freeport and Rockville Center. Also the extremes of weather varying from late summer to mid-winter.

The importance of this line as a trunk required construction of great strength and dependability to carry 60 lb. per sq. in. pressure, with the prospect of this pressure being increased from time to time up to 100 lb. per sq. in. These factors governed the decision to construct a welded line. The pipe specified was 12¾-in. O. D., weighing 50 lb. per ft., to be delivered in double random (40-ft.) lengths. The advantage of the double random lengths in reducing the number of joints is obvious, and no difficulty was experienced in handling them.

---

*Paper presented at Annual Meeting, A. W. S., April 24, 1929.
†E. L. Phillips & Company.

Surveying and Locating Route

Part of the route was along an oiled roadway which was at variance with the actual right-of-way and might be moved at some future time. Sufficient care was taken to locate true property lines and locate pipe route in such position that future concreting would not cover it. Along part of the route it was necessary to cut away brush, to mark out line and give clearway for the digging machine. The next consideration was to locate depots for shipment of pipe at advantageous points. When pipe was received at these depots it was laid in layers with plank runners between and chocks under each pipe, a safety precaution we have found quite necessary. The advantage of laying pipe in this way is that it can be rolled by hand to the edge of the stack where it can be picked up by derrick truck and loaded on trailers.

FIG. 1 — OXYGEN AND ACETYLENE MANIFOLD AND GENERATOR WAGON

FIG. 2—WELDING POSITION FOR ROTATING WELDS

Pipe was hauled on trailers, 10 lengths to a trip, and strung along the route. Care was taken to lay out approximately correct footage to minimize shifting later, to keep cross roads and driveways clear and to keep pipe well out of traffic and chocked where open going permitted, otherwise pipe could be strung out only for a day's work ahead of welding.

Ahead Welding Gang

The ahead welding gang under direction of the ahead welding boss is responsible for lining up pipe, tack-welding, welding lengths together, usually in groups of five, and tieing-in fives to form strings of 10 lengths.

The ahead boss was assigned a 2½-ton, A-frame derrick truck with chauffeur, line-up leading man and four helpers. This group enabled him to get pipe in trailer loads of 10 pieces wherever circumstances had not allowed the pipe to be strung out along the route previously by another truck. Two or three loads were sufficient for the normal day's output of the crew engaged.

The 40-ft. lengths, weighing one ton apiece can be handled by crowbars, the idea being to line up five lengths if conditions allow. All lining up is done on 4 x 4 skids and if the route is not straight, skids are blocked to give a straight lay for the five pieces so that they can be rolled without strain when welding starts.

The use of the derrick truck to lift pipe on the skids is efficient; particularly where it has been necessary to string out pipe on the opposite side of the road from which welding is to be done.

A long handled wire brush is pushed through each length of pipe before lining up to remove all dirt and foreign material from the inside, ends of welded strings later being plugged with wooden stoppers.

Particular care is given in lining up to insure ¼-in. space between abutting ends of the pipe, *as no precaution is more essential to successful welding.* A¼-in. welding rod serves satisfactorily for spacing. When the lengths are properly lined up and spaced, a welder with a portable outfit makes the necessary tack-welds. While the usual routine is to line up and tack-weld five lengths, this must be varied according to conditions encountered. Sometimes only two or three lengths could be welded instead of five and these doubles or triples were handled back to a suitable point where they are left side by side to be joined later by the follow-up welding gang at the time of actual trenching and laying-in.

The normal procedure in welding was to have four welders working simultaneously, joining the five lengths as they were turned over by a helper using chain tongs. The line welders were supplied with oxygen and acetylene from a 200-ft. double manifold of ¾-in. welded pipe provided with cock outlets at frequent intervals, Fig. 1. This manifold was attached to the gas wagon which was simply a retired Ford chassis on which were mounted an acetylene generator and cylinders of oxygen. This arrangement proved to be very satisfactory as the entire outfit, including manifold, could be easily moved from one position to another.

The ahead welding boss was responsible for organizing his unit in such a way that there would be no delay due to lack of material or supplies at any time. For the greater part of the route water for the generator had to be trucked because there were no hydrants. Long narrow tins were made up for this purpose. The assigned truck took care of supplies of water, carbide, welding rod, oxygen, tool boxes, equipment and the transportation of the gang itself.

Welding

The conditions governed by traffic and residences along the greater part of the route made it undesirable from the standpoint of public convenience to weld continuous strings in routine without care in selection of locations in which to leave completed strings for the laying-in gang. In consideration of these conditions a minimum output of 4 welds per day per welder was set for the ahead boss, considerable resourcefulness being necessary on his part to accomplish this. As his unit was limited in size it was arranged to use welders in pipe shifting in cooperation with the other members of the unit between welding periods.

Once started, the welds had to proceed together without interrup-

tion until finished, the time being usually just short of one hour. Continual vigilance was exercised to secure complete and uniform penetration to the bottom of the vee. Some of the more important welding details are as follows: Pipe, National Tube Co. lapwelded, 12¾-in. O. D. with ⅜-in. wall; welding rod, ¼-in. high strength; oxygen pressure 25 lb. per sq. in.; acetylene pressure, a few lb., as blowpipes were injector type.

Blowpipe is held in the usual way, pointing in the direction of the advancing weld, the point of welding maintained as pipe is rolled at easiest working point for welder on top quadrant, Fig. 2. It is to be noted that with this size rod and ⅜-in. pipe wall, the tendency is to move rod and flame back and forth together rather than in opposite

FIG. 4—SHOWING USE OF TEMPLET IN FABRICATING AN OFFSET BEND

FIG. 3—AN INTERESTING WELDED SPECIAL

directions as can be done with thinner walled pipe and smaller rod. Welders have individual characteristics in modification of this and in rapidity of motion and it is not advisable to attempt to change welders' peculiar characteristics in this respect as long as penetration to the bottom of the vee is secured, metal well puddled by rod and flame, and honest reinforcement made. Welders are, however, coached not to disturb puddle to the extent of losing protective film. Weld is made 1⅛ to 1¼ in. wide and reinforced ⅛-in. Welding is done continuously in the same direction until completed, followed by a few minutes reheating gradually around the weld to insure slower cooling off. Each welder is assigned a number die which is stamped on the flattened end of a short piece of welding rod and welded into each joint that he makes. Following the main welding crew is another welder under the direction of the ahead boss who makes a tie-in weld joining two groups of five lengths into a ten length string. This welder uses a portable outfit which gives the mobility necessary for alternating between tack-welding and tie-ins.

Use of the acetylene generator for line welding proved to be very satisfactory and most economical. Its limitations in keeping welders together in a group was taken advantage of in facilitating close inspection and control of routine in welding. The only difficulty experienced with the generator was during very cold weather. While the

generator is operating sufficient heat is evolved to keep the charging water from freezing but some trouble was experienced with freezing in external piping, particularly in sludge discharge. This objection is being met by the manufacturers by placing all piping within the generator shell and can further be overcome by lagging the entire generator and installing hot water heating coils supplied from a small external kerosene boiler.

Welding Costs

A generator charge of 100 lb. carbide and 100 gal. water was found sufficient to make 9 welds. On the basis of 450 cu. ft. of gas generated this gives an acetylene consumption per weld of 50 cu. ft. Actually we used a charge for each 8 welds, as this permitted two sets of operations per charge, the remaining capacity being used for reheating and tacking, making 56 ft. chargeable to each weld. Sixty to 80 cu. ft. of oxygen and 3½ to 3¾ lb. of welding rod were used for each weld. Consumption of acetylene from cylinders ran 59 to 69 cu. ft. per weld.

The acetylene generated from 100 lb. of carbide proved to be equivalent to that obtained from 2½ cylinders of dissolved acetylene in actual use. As to value it can be stated that 100 lb. of carbide at $5 will give more welding heat than $13 to $15 worth of dissolved acetylene. The material cost of our 12-in. welds using generated acetylene, including carbide, oxygen and welding rod is $1.85 per weld, or using dissolved acetylene, $2.585. To make a practical charge against welding in our cost accounting, the entire ahead welding unit is charged against the routine output for the day. As the work of aligning pipe is here considered as a charge against welding except for a proportional amount of time of truck and men for hauling pipe from depot or shifting pipe from the position necessitated by traffic conditions, the ahead welding gang is listed on the basis of a day's output including one hour for each man for transportation:

1 boss welder	2 line-up men
5 welders	½ time chauffeur
2 welders' helpers	½ time 2 truck helpers
1 line-up leading man	

The output of this gang for a day, two 10-length strings, or a total of 18 welds furnishes the basis on which labor costs per weld can be determined. It is possible to argue that the true charge against welding is the cost of the material plus the welders time only, which will give a very pleasing figure; and further, if the reinforcement is cut down 25 per cent a still lower cost may be arrived at, suggesting a bargain price. Numerous modifications could be made, all reasonable, depending on the particular method of cost accounting used. Labor on welds could be handled by piece work as is done by some contractors.

Whereas a minimum output was set for a head boss of 4 welds per day per welder, actually 5 welds were made frequently and 6 occasionally, and under favorable conditions 6 welds would be a fair basis upon which to figure costs. As our object first and foremost was to make the strongest joints resonably possible, it was not considered desirable to cut down

the reinforcement, and the requirement of 4 welds per day from each welder gave us in the long run, through bad weather and all conditions, a steady production which was lived up to. It should also be borne in mind that while a figure representing cost of weld on basis here given may appear to be an expensive joint as compared to other types, there is considerable saving in trenching and digging bell holes particularly where this is necessary in loose sand and water conditions. No other type of joint could stand the rough handling and allow the simple means of lowering that long strings of welded line offer the lay-in gang.

Cost increases for position or tie-in welds and for specials. For cutting and fitting under certain obstructions there is no better way, and occasionally no other way, so that comparison of costs is not the only

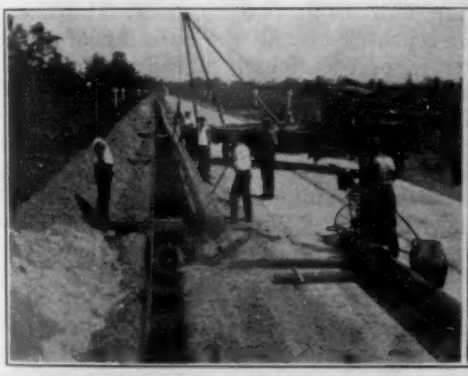


FIG. 5—MANEUVERING OVER TRENCH BY MEANS OF DERRICK TRUCK

FIG. 6—BULL HEAD THAT WILL NOT BLOW OFF THE END OF THE PIPE FABRICATED BY WELDING FROM DRESSER PARTS

consideration. Good management of the follow-up welding can eliminate excessively costly welds by changing the other factors of the job. In general, we have found that the labor on follow-up welding, including all specials, can be kept at a figure not greater than 50 per cent more than routine work. Any increase over this amount is due to delay in preparing for welders' work caused by other factors of the job.

Follow-up Welding Gang

The follow-up and special welding is under another boss welder using two or more welders. This job I consider is for the foreman welder of the job, having under his jurisdiction the ahead boss and transportation and interchange of welding equipment and personnel. He should have angles prepared ahead of the job where turns in the route are required and take care of special angles and offsets where excavation uncovers subsurface obstructions to be passed, Figs. 3 and 4. On this line there were 16 culverts and bridges of various types, all requiring offsetting, and frequent offsetting was necessitated to avoid cutting into concrete cross road wings.

Free use of Dresser couplings, long type 40, was made for expansion

purposes and for tie-in when this means was quicker and cheaper. All offsets, tees and drip pots were considered as anchors and were Dresser coupled each side. Valves of the Merco-Nordstrom venturi type with flanges were tied in by means of 2-ft. nipples, Van Stone flanged on one end. One nipple was welded into the line on the pressure side, and the other nipple tied in with a Dresser coupling. Dresser couplings are preferred for position tie-ins involving joining of two long strings already backfilled, where abutting ends are not free to move together under contracting force of cooling weld.

A brief description will now be given of the organization for the other necessary operations on the job.

Painting

Like the welding, the painting unit is in two sections: The ahead gang and the follow-up gang for touching-up and the painting of tested welds. Following the welding crew, or occasionally ahead of them is a gang consisting of leading man and four helpers, having paint supplies, barrels of bitumastic enamel already strung out, and a 100-gal. Littleford kerosene torch heated kettle. This gang first takes care of the routine of cleaning the line with brush and cloths, and in freezing weather, drying frost from pipe with portable torch and applying priming coat by means of long handled brushes. Priming is kept one to one-half days ahead of the enameling.

Excavation

The next unit of operation in order is the trench opening gang and boss. Practically the entire route of this job was dug with a Barber-Greene ditcher, operator and helper. The boss of this gang supervised the line-up of the trenching machine and had a pipe fitter or competent man look ahead for cross services, especially other mains on cross roads. Such obstructions were test-holed and cleared to eliminate damage by machine buckets. Even so, trench buckets occasionally ripped into unsuspected services. In time considerable ingenuity was developed in handling repair in such situations, whether gas or water. No chances were taken, however, with water mains as this type of accident is costly and an annoyance to the public, and may throw the job out of routine.

Laying-in

The next operation is that of the laying-in boss, with 2 helpers and a well equipped 5-ton A-frame derrick truck, operator and helpers. An outstanding feature of this part of the work is the successful attempt to get away from the group of 8 and 10 tripods and chain falls formerly used in lowering long strings. These are undesirable because of danger to personnel and the inefficiency of so many working units. The routine of the laying-in gang first includes clearing ahead for the passage of the digging machine, maneuvering the string so that it lies alongside of the machine on the same side of the road, or if conditions demand, shoving string to opposite side of the road. After the trench is prepared and cribbed, the string of whatever length is maneuvered over the trench on skids, Fig. 5. Sets of four 4 x 4-in. x 7-ft oak skids, with base blocks well away from the edge of the trench, are set at intervals of 80

to 100 ft. In lowering, one end of the string is first lifted from the skid by means of the derrick. The skids are removed and the end of the string lowered away into the trench, the end of this string having been previously plugged and again examined for obstruction before lowering. With the pipe resting in line along bottom of trench at a depth of 4 ft. the flexibility of the pipe is such that it resumes a horizontal position again above supporting skids 120 ft. distant and the effect of the lift at this point is continued for another 80 ft. so that when lift is made to removed supporting skids 200 ft. of pipe must be lifted, or about 5 tons dead weight. Blocking at the rear of the truck frame is required to handle this lift. When the lowering away of an end occurs the second group of skids gets a heavy strain concentrated against the skid on the end. As this one flexes, the next one takes the load and so on until the load is distributed over the four. Oak 4 x 4's used in groups have been found easier to handle and more dependable than single heavy skids. No fear is entertained of the effect on the welded pipe of a sudden drop in the trench, but rather injury to cribbing of trench and danger to nearby water of gas mains. When the string is lowered it is pulled by truck winch to the point of fit with the string previously laid in. The end is then lifted for cleaning and installation of the Dresser coupling, collar, gasket and sleeve being slipped back so that the pipe can be lowered to butt against the other pipe end. Pipe ends are raised or lowered or wedged sidewise to make an easy fit. A distance of 1 in. is usually allowed between pipe ends and occasionally when pulling back is limited, a space as much as 4 in. to 6 in. is allowed as the Dresser coupling used is a long type 40. There is no objection to bringing pipe ends together inside the sleeve as there is nothing to fear from pipe expanding and causing compressive strains. This is not true, however, when joining up to an offset piece as a compressive force at such a point might strain the weld on the outside of the angle.

One of the advantages of a welded string is its ability to accommodate itself to curves in the route. Advantage is taken of this except when an excessive curve requires hot bending to relieve undue stresses.

All pipe laid is rammed with fill under the base.

The lay-in gang is the pace setter for the whole job. I am speaking now of laying pipe through built-up sections with services, driveways, cross roads and cross mains to contend with, made still more difficult where loose sand, requiring cribbing, and water conditions are met. A large proportion of the pipe on this job could not be laid in by vertical lowering, but in many cases had to be pulled above the trench to a position several hundred feet from its final resting place in order to select a satisfactory point of entry for pulling under cross mains and services, and not to disturb crib bracing. For this pulling and snaking in the trench two winch trucks are occasionally resorted to. Above the trench strings could either be dragged on sand piles to avoid injury to enamel, or by the use of a low 6-in. roller carriage. *Upon the resourcefulness of the laying-in gang may depend the whole efficiency of the welded pipe job.* Under straightaway conditions it is obvious that several thousand feet a day could be laid by one crew, but such conditions are the exception rather than the rule on a line of this type.

Testing

One man is responsible for testing, taking care of a compressor for this purpose and ordinarily making all Dresser tie-ins. Testing is an expensive inconvenience as line has to be left broken at intervals to allow installation of test bull heads. Back-filling cannot be done until testing is completed and joints painted and enameled. When possible two ends of pipe are left overlapping with bull heads installed on one or both, to avoid later insertion of a nipple to fit. One piece is allowed to rest on the other so that after test and removal of bull heads, a single cut can be made with the blowpipe and tie-in Dresser installed. It is preferable to arrange for test ends for each day's work or at most 3 days' work. There are two reasons for this. The first is that the shorter the line tested with recording gauge over a 24-hour period, the more effect a small leak will have on the chart. The second reason is that of public annoyance and inconveniencing the back-fill gang. Toward the latter part of the job more and more effort was made to test strings above the trench, largely made possible by the invention of Foreman J. Krupa of a very satisfactory and safe test bull head, Fig. 6. This allowed pumping the string with air at 100 lb. pressure, hammer testing the welds, followed by testing with soapy water, painting and enameling, allowing the string to be laid and back-filled at once. We have not yet succeeded in cracking any welds on this job with the sledge. The man making the test is allowed an hour overtime for each leak found, which is pointed out to the foreman welder, the number of the welder is noted and disciplinary action taken. We are very anxious to discover any leaks at this time as a later failure of a chart test makes a very miserable job to tackle, especially if chart shows a very small loss such as a pound or two over 24 hours. No dependence is placed on the chart showing until the second 24 hours, as the air from the compressor is quite warm and in cooling will decrease the pressure. Consideration is given to any appreciable change in temperature during test.

Hard Job Gang

In order that there may be no undue delay at any point there is a hard job gang which is quite complete though small. If in the routine described above the job arrives at a culvert or a bad water condition, or one of the dozen special circumstances which would throw everything out of gear, a gap is left and the work is continued as before. The hard job gang then tackles the special job, doing the necessary testing of the individual job and tieing-in with the ends left by previous routine on each side. When a long route of hard going is struck, requiring most of the main gang, any excess men not immediately needed are shifted ahead to the next easy-going section to get as much footage of piping in as possible, so that when a delay occurs which would kill footage output for the day or several-day period, footage is not entirely lost.

One example of how welding pipe construction can lend itself to very difficult substructure and water conditions is the following:

It was necessary to cross a concrete thoroughfare accommodating heavy traffic which ran in a valley at right angles to our route. The

crossing was also a low surface point, and among the various subsurface pipe and conduits was encountered a 60-in. trunk sewer which we had to pass under. Water showed up in the trench at a depth of 3 ft. In order to pass under the 60-in. pipe we had to go to a depth of 9 ft. Trenching and solid cribbing was accomplished with considerable difficulty due to quicksand and springs. It was necessary to double bridge the crossing for two way traffic and to avoid excessive pumping which would undermine the roadway. We trenched back 100 ft. to one side of the sewer from a 9-ft. depth gradually to a 6 ft. depth, lowered a prepared and tested welded double, attached a pull strap by welding and pulled the pipe, with one end open, quite out of sight in the silt below sewer, finally bringing it across the road to a low point which allowed box cribbing and a safe place to pump. The pipe was then flushed thoroughly clean and pumped out. Thus 80 ft. of tested and enameled pipe was installed in a location that would not have allowed any type of coupling to be put in place.

Gassing Out

Valves were installed at strategic points from an operating standpoint at intervals of approximately 2 miles with provisional nipples 6 ft. long in between for future valve installation. Gassing out was accomplished by use of purge connections made by welding into the 12-in. nipple, on the pressure side adjacent to the valve, 2-in. nipples to which were connected Merco-Nordstrom cocks.

Conclusion

Inasmuch as this was only one of a number of jobs being done by our division, it was sometimes necessary for the proper balance of the entire division to rob the job of men and equipment, and at other times to absorb a temporary excess of labor beyond comfortable handling. I have not attempted to describe a job which is an example of speed or unusual economy, but simply an actual job proceeding under average conditions.

All Welded Barge

E. H. EWERTZ†

A ONE THOUSAND ton steel deck barge for Lee and Simmons is being constructed by the Electric Boat Company from a special design made by our Company.

All who have been in touch with ship construction for the last ten years are familiar with the ever increasing use of electric arc welding on shipboard; but few ships have heretofore been built with the entire omission of riveted joints; nor can such a structure be built

†Ewertz and Dalcher, Consulting Engineers.

unless the design from the beginning has been thoroughly worked out and calculated with this end in view.

Before the welded ship became practical, steel and iron ships have been held together by rivets. This construction requires first a detailed plan or a wooden mold showing the location of each rivet; the cutting and bending of the material to the actual curvature or size; the punching and/or drilling of the holes; the bolting in place, the driving of the rivets; and in case of watertight work, the chipping and calking of the riveted seam; all of which takes time, and the employment of a half-dozen or more different trades during the process of laying out and erecting. The punching of so many holes in straight lines through a plate or in the framing reduces the strength of the section sometimes as much as 25 per cent or 30 per cent. Much of

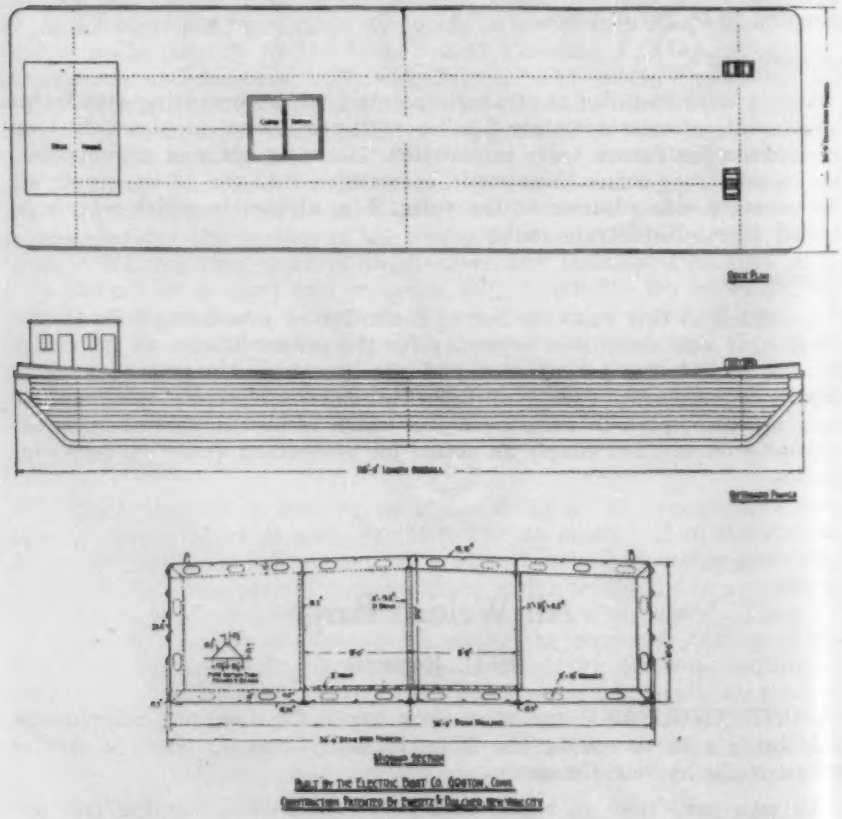


FIG. 1

this work is eliminated in the electric welded ship, and for equal strength the weight of material may be reduced as much as 20 per cent; which saving may be applied to increase carrying capacity of

the ship; or if power-driven, a saving in displacement may be reflected in the power required to drive the ship. On account of the decrease in weight of material and hours of labor, it is considered that substantial savings in cost can be made as compared with the conventional riveted construction.

The principal dimensions of the Lee and Simmons barge are as follows:

Length overall	118 ft.
Max. Beam over fenders	36 ft. 6 in.
Depth at center	11 ft.
Deck Load carrying capacity	1,000 tons
Cargo space in hold	16,000 cu. ft.

The barge is sub-divided by two longitudinal watertight bulkheads; two transverse watertight bulkheads near the ends; and one non-watertight transverse bulkhead amidships.

On the after end of the barge there is erected a steel house for living quarters, with space provided for a power cargo hoist, if desired.

The bottom of hold throughout cargo space is sheathed with a wooden floor, and all compartments below decks are thoroughly ventilated.

In preparing the design, the requirements for quantity production have been kept clearly in mind throughout so that a yard with a limited water front or with few launching ways may assemble large sections at any convenient spot and transport them to the launching ways for erection. All shell and deck plates of the same thickness being of identical dimensions are largely interchangeable throughout the structure. When flanged at the mill, all such parts may be delivered directly from the cars to the structure without first going through the yard fabricating shops.

It will be noted from the illustration that a 3 in. flange is turned on one longitudinal edge of each shell or deck plate. The longitudinal edge of the adjacent plate is butted against this flange member and welded thereto so that each longitudinal weld is reinforced by a 3 in. flange giving great strength to the joint. The transverse frames are made of flanged plates 12 in. deep and of triangular construction, the hypotenuse of the right angle being placed against the shell of the barge and intermittently welded thereto. As these flanged plates are cut to length at the mill, fabrication required at the yard is reduced to a minimum. The fenders are of special shape and construction as shown; wood-filled and welded to the outside shell plating. They form a very strong fore and aft tie, and on account of their special shape will prevent riding on adjacent barges.

All welding will be done under the most careful supervision, and by workmen who have first qualified by tests adopted by the American Welding Society. Electric welding will be used throughout from power furnished by 300 ampere welding machines. All material entering into the construction of the barge will be of a grade to meet the American Bureau of Shipping specifications.

Thermit Welding of Rail Joints for Main Line Tracks of Steam Railroads*

J. H. DEPPELER†

WE won't admit that we in America are in any way behind the European Continent in welding matters; in fact, talking from the standpoint of the Thermit Welding Process we're years ahead. This does not in any way reflect on their ability, however, because their engineers, metallurgists, and physicists are every bit equal to ours and their opportunity to carry out investigations due to the universal recognition of the importance of research and the excellent cooperation of the industries with the Universities and the governmental departments has made research and investigation to a great extent more important than monetary return.

But given the same process and the same materials and left alone long enough, two equally resourceful investigators naturally would develop different processes and meet with a variety of problems the solution of which would bring them to different end points.

In America the Thermit Process has been developed primarily to take advantage of the great purity of the steel produced by the Thermit reaction with the result that the welds are rarely unsound and have physical qualities to compare with ultra-refined electric furnace steels: strong, ductile, and shock-and-fatigue resisting. The natural result is that although it has made enormous strides in replacing mechanical joints in the joining of street railway rails—its most spectacular application is found in the steel-mill, the railroad shop and the shipyard. In Germany, on the other hand, by far the most important use for the process is found in rail welding.

As the European rail welding system differs from ours, a brief description of the development there and here may lead to a better understanding of the situation.

In America labor is relatively expensive and our street railway's track-laying programs require that one Thermit gang of eight or nine men step along at the rate of thirty to forty joints each nine-hour day. In Europe they take things a little easier, and half this number is a good day's work. Furthermore the American program requires that the track gang keep well ahead of the welders and the welders out of the way of the paving gang. Here, therefore, it is usually impractical to move each rail length as the welds are made and the process takes this into consideration.

Through various steps we have developed the "Insert Weld" with which most of you are familiar. It has strength and wearing qualities

*Paper presented at Annual Meeting, A. W. S., April 25, 1929.
†Chief Engineer, Metal & Thermit Corporation.

equal to the rail itself, 100 per cent electrical conductivity, can be installed at a rapid rate, and requires no moving of the rails as each joint is made; in fact, the rails can be completely embedded in concrete as long as an opening is left at the joint. Almost 100,000 of these are being installed every year. This same weld has lent itself admirably

FIG. 1—APPLYING THE CLAMP—GERMAN PRACTICE

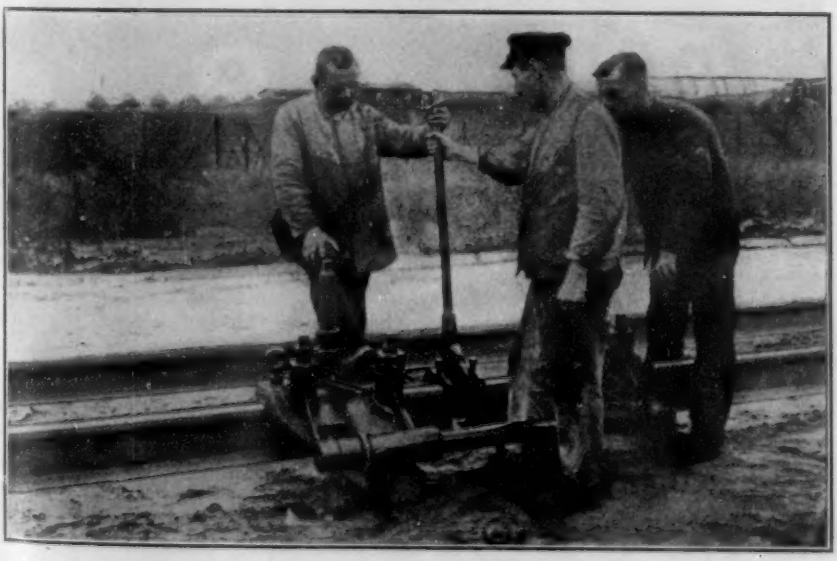


FIG. 2—MILLING THE RAIL ENDS—GERMAN PRACTICE

to installation "under traffic," a recent development which although a little more expensive nevertheless is quite practical.

Now in Germany they have developed a slightly different type of weld, in which the base and web of the rail are fusion welded and the rail head pressure welded. This joint has the advantage of a little greater resistance to negative bending moments and theoretically at least a slightly greater economy in the use of the Thermit as the heat of both the Thermit steel and slag are used. The disadvantages are obvious, the necessity of using cumbersome clamps to force the rail heads together to produce the pressure weld and the necessity of submerging the track-laying program to the welding operation because of

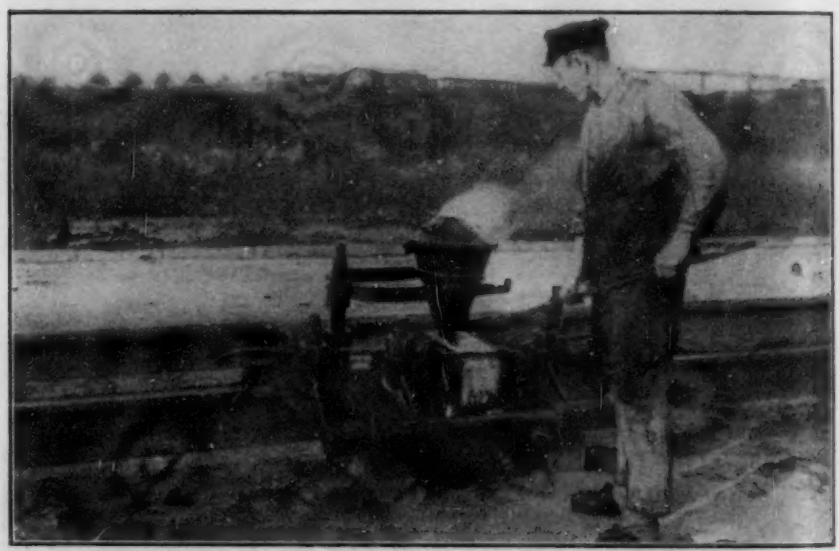


FIG. 3—TAPPING THE CRUCIBLE—GERMAN PRACTICE

the necessity of moving the rails ¼ in. or so together as each weld is made, limiting the operation to the making of only two joints at a time on each track.

But our "Insert Weld" did not lend itself so well to the welding of open track as did their pressure weld, and because of the feeling that rail expansion due to temperature changes might cause buckling and contraction and cause breakage we have not ventured very far into this field and our experience along this line is very limited.

In Germany, however, conditions were a little different and through a friendly cooperation with the German State Railways much important work has been done which should be very helpful to us and to the railroads of the United States. The German Thermit Company's problem was simplified also by the fact that their rolling stock and equipment was relatively light—19-ton axle loads being considered heavy—and their rails correspondingly light. The heaviest German rail today

weighs only about 100 lb. per yd. as compared with our present 140 lb. and our prospective 200 lb. per yd. Their rail steel, too, is much softer, about 0.40 C. against our 0.70 to 0.80 C.

Their open track experiments started about 1924, in the Nürnberg region, on a much used lead-in track to a freight yard. From 16 to 26

FIG. 4—PULLING UP ON THE DRAW BOLTS TO MAKE PRESSURE WELD—GERMAN PRACTICE

FIG. 5—REMOVAL OF SLAG—GERMAN PRACTICE

freight trains passed into this yard each day. The total length of track welded was about 4000 ft., welded into lengths varying from 200 ft. to 360 ft. with carefully adjusted and positioned expansion joints between them. Naturally everything was very carefully done—the expansion joints set for the temperature at the time and careful calculations made of the tensile and compression stress in the rail under all possible conditions and the shearing stresses on the expansion joint bolts. There was nothing unusual about the construction otherwise, some screw spikes were used and some ordinary ones—nails, they call them—and ordinary ties and ballast. There were a few anti-creepers installed near the middle of each welded stretch.

FIG. 6—FINISHING THE JOINT WITH A HAND FILING APPARATUS—GERMAN PRACTICE

The results were excellent, they had no breaks and the smoothness and quietness of operation was very striking.

In May, 1928, when I inspected this track it was in excellent condition except for the expansion joints—these had spalled off on the sides and sliding contact faces and had long since stopped functioning as expansion joints. So here in reality we had 4000 ft. of track with ordinary bolted joints at the ends—straight track and curves—with no broken rails and no spreading gage although the temperature variation was normally from 4 deg. Fahr. to 104 deg. Fahr.

Subsequently the Nürnberg classification yard was welded up solidly and the effect of the uncoupled cars sliding in noiselessly was almost uncanny.

Near here also was a longer experimental stretch finished in 1927—a perfectly straight piece 1000 ft. long and with ordinary bolted joints at the end. This track, they say, was welded when the thermometer

was 40 deg. Fahr., the bolted joints being left about ⅜ in. open. When I was there in May, 1928, the temperature was 80 deg. Fahr. and the bolted joints at the end of the 1000 ft. were still ¼ in. open. In other words, the welded track did not behave as a steel bar free to move would and where a 40 deg. Fahr. change in temperature would cause a lengthening of about 3 in. in 1000 ft., but instead lengthened only about ¼ in. and half of this at each end.

Shortly after these early experiments the engineers of the State Railway decided that it must be perfectly safe to weld the rails on the steel railroad bridges because here the expansion of the bridge members and of the rail would be the same and therefore there could be

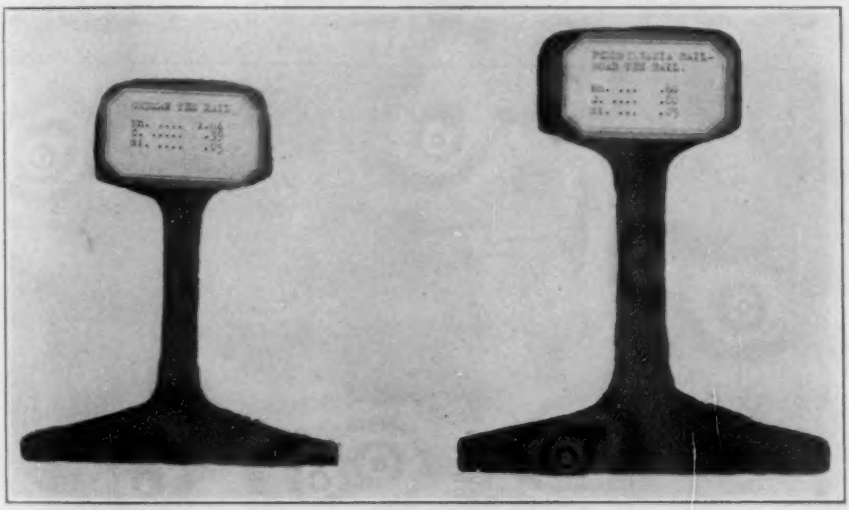


FIG. 7—COMPARISON OF GERMAN AND AMERICAN RAIL SECTIONS

no fear of buckling or of rail breakage. Many such installations have been made, but I had time to inspect only the bridge across the Rhine at Cologne and the entire absence of noise as the fast passenger trains glided on and over the bridge was very noticeable.

Another general application which the German engineer readily agreed to was the welding of the rail in tunnels. Here the bolted joints and their maintenance present a more serious problem than anywhere else.

A notable example is the tunnel on the Frankfurt main line track at Schlüchtern. This tunnel is about 12,000 ft. long and the cold damp air within it and the poor ventilation combined with the gases from the locomotives rapidly corroded away the splice plates and bolts at the joints and to a considerable extent the tie plates and spikes. This tunnel track had to be entirely rebuilt every four or five years and required almost constant maintenance. The Thermit welding of this track was started late in 1924 and at first the joints were completely

eliminated in the 4000 ft. located in the middle of the tunnel. The rest of the rail was welded at the side of the track in 300-ft. lengths and positioned in place of the old track between trains. These shorter units were found more convenient to handle and there was less danger of disrupting train schedules. With practically all the fish plate and bolt corrosion troubles eliminated they solved the tie plate problem by using fibre plates and instead of the lighter spikes used heavy-headed screw spikes. The few bolted joints remaining in this tunnel are easily maintained and although there has been insufficient elapsed time as yet to tell definitely, without doubt the life of this tunnel track is at least doubled and probably quadrupled.

Near Berlin there is considerable freight track welded in 1000-ft. lengths and at one place they have parallel with the welded running

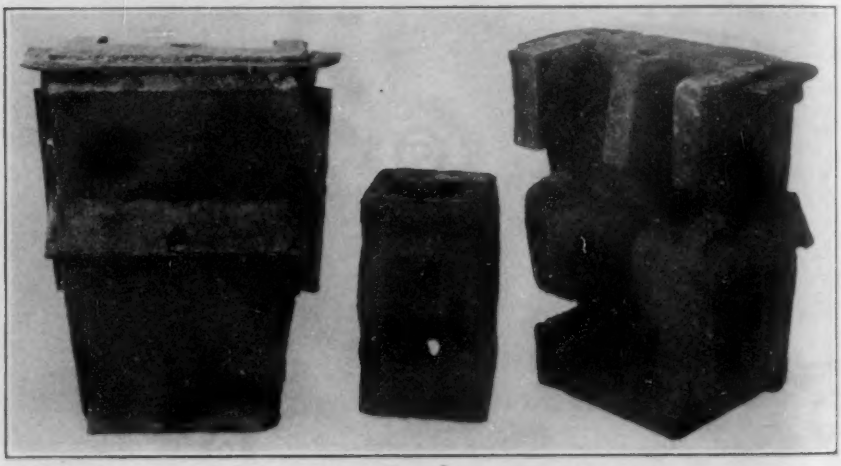


FIG. 8—AMERICAN DESIGN OF WELD FOR THERMIT PRESSURE WELDING OF RAIL

rail a welded rail mounted on rollers and this length almost obeys the law of expansion, so to speak, but the track itself does not.

The general observation is that in a given length of welded rail the 40 ft. on each end seems almost free to move according to temperature changes while any length of rail between these ends stays practically stationary. So from the standpoint of expansion and contraction an 80-ft. rail behaves no differently than the 1000-ft. one and probably 2000 ft., or even endless rail would be perfectly feasible were it not for the present difficulty of repairing a broken rail—and broken rails will occur in spite of all precautions.

The German engineer at first naturally feared the effect of the welding heat on the rail steel and required the safeguard of plates around the Thermit joints. Our engineers will undoubtedly feel the same way at first, but let us hope that like the Germans they, too, will quickly gain confidence and find this extra expense unwarranted.

Last year in Germany the State Railways embarked on a regular program of welding on their main line tracks and started the elimination of half the mechanical joints—converting 50-ft. rail lengths into 100 ft. Their initial order called for 60,000 welds. This work was under way when I was there and was very interesting. The new rails were welded on loose ties along the side of the right of way and between trains lifted over and spiked into place. It is expected that shortly the rail mills will be delivering 100-ft. rails and then it is their intention to weld every other joint of these, making lengths of 200 ft.

Although the bulged fish plate is no longer used as a precaution against welded joint breakage, nevertheless they do use a double tie at the joint. The German practice of placing their joints opposite eacn other instead of staggering them as we do in this country allows this double tie to serve two welded joints.

There are other differences between the railroad construction in Germany and here which I mention not because they are pertinent to

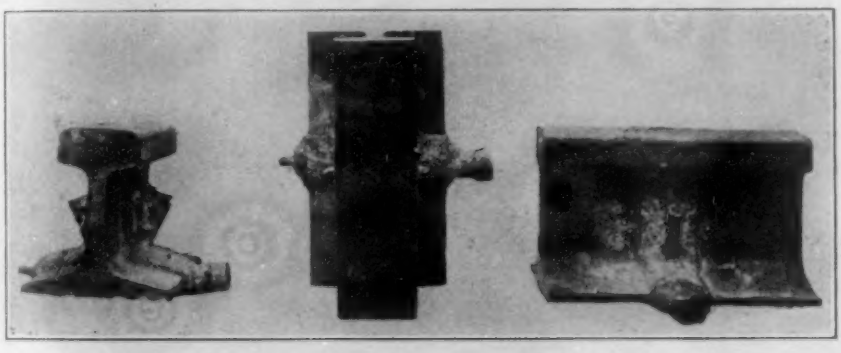


FIG. 9—THERMIT PRESSURE WELDS OF AMERICAN SECTIONS NOT YET GROUND OR FILE FINISHED

the welding problem, but because they may help us to more completely understand the situation.

They like screw spikes—we tried them and in most cases went back to the ordinary spike. But they use soft wood (yellow pine) ties and when the screw spike pulls out they drive into the worn hole a creosoted hard wood plug made for the purpose by the Dübele Works which plug is tube-like and grooved on the outside and threaded on the inside to receive the screw spike. They have also done a great deal of experimenting with pressed steel ties about the same overall dimensions as wooden ties and dished concave downward (small elongated inverted bath-tubs), with lugs and ribs to receive the rail. The regular crushed stone ballast is pressed tightly into these and they seem to stand up very well. They are drum-like, however, and operation noises are increased.

In addition to the obvious advantages gained by the elimination of the rail joints there is one less obvious, but of no less importance, and

that is the effect on creepage. I may miss my guess but I believe this evil is responsible for the present very strong feeling the American railroad engineer has against long welded rails. He says he fears spreading gage due to rail expansion and wants the flexibility of the bolted joints with the ¼-in. to ½-in. gaps between the rail ends. But these conditions exaggerate creepage and slowly but surely the rails walk along usually in the direction of traffic and the excess must cause a bulging and spreading of the gage, especially at curves. Ideas for the prevention of this creepage literally fill pages of the Patent Office

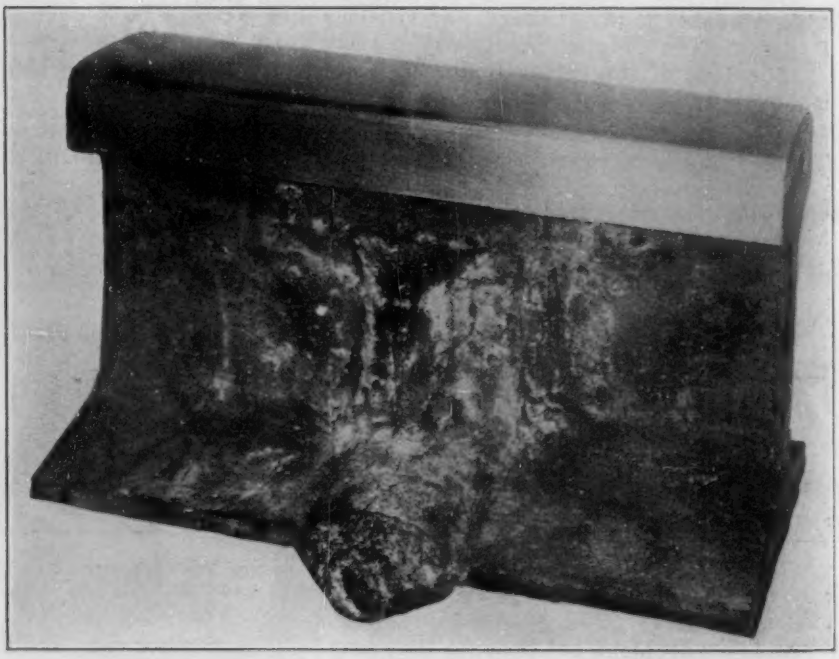


FIG. 10—THERMIT PRESSURE WELD ON 140 LB. T RAIL FINISHED

gazettes and the anti-creepers already in use chew their way slowly through the sides of the wood ties.

Creepage, I believe, is caused by the "measuring-worm" effect of the short rail lengths—the receiving end of each short rail is pressed down in a slight arc by each passing wheel, contacts the tie plate where it grips and the rolling wheel proceeds to iron out the rail in the direction of traffic. In a short time the curves have widened out and the track gang is called upon to realign and resurface the track.

The elimination of each joint decreases creepage and in the 1000-ft. welded stretches it has been found that it is reduced to only about 10 per cent of that of a similar length of unwelded rails. One welded curve I inspected near Nürnberg had, their records show, to be re-

surfaced every month before the track was welded, and afterward they hadn't had to touch it for two years.

Then this same Dübele Works that made the hard wood plugs, also make a poplar-wood plate about ¼-in. thick designed to slip between the rail base and the tie plate—poplar-wood, they say, presents the greatest friction and tends to prevent creeping. Their use requires slightly higher ribs on the tie plates but we believe these are beneficial anyway on welded track.

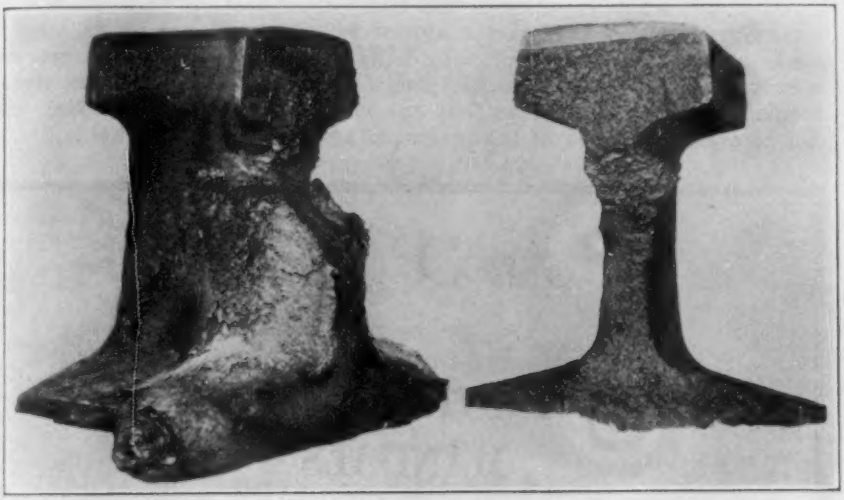


FIG. 11—THERMIT PRESSURE WELD AFTER TESTING. TEST MADE BY BREAKING RAIL HEAD DOWN AFTER SAWING PARTLY THROUGH HEAD TO CAUSE FRACTURE TO OCCUR ALONG PRESSURE WELD SURFACES

Since my trip abroad I have become quite enthusiastic about the possibilities in this country and we have conducted extensive research on the development of the necessary clamps and other apparatus and particularly on the making of a suitable Thermit weld for our heavy high carbon rails. The problem was not so easily solved. In Germany they face the ends of the rail heads and place between them soft iron plates which they say assist the pressure welding of the rail heads—we believe the soft iron in the running surface of our high carbon rails would be objectionable and our experiments have proved it unnecessary. Our pressure weld of the rail heads is as perfect as the rail itself.

Then another difficulty became evident. The alumina slag of the Thermit reaction is used, you know, to furnish the heat for the pressure welding of the heads and regardless of how this slag was distributed around and along the rail head in the welding operation it would either not penetrate to the center of the head or it would penetrate but fuse away the rail surfaces. This difficulty was finally overcome by a mold design and a peculiar slag distribution which makes

the operation very simple and absolutely dependable. This work was also facilitated by the design of a new Thermit much more suitable for this type of pressure weld than that which we ordinarily use in the industry.

You probably would not be interested in the details of the device for facing the rail ends in the field, nor the light portable preheaters we are developing—gasoline engine driven, of course, because electric power will not be available along the railroad right of way—and it will be sufficient therefore to say that we have already installed a number of our new welds in the hump-classification yard at DeWitt, near Syracuse, N. Y., and are almost ready to proceed on as large a scale as the American railroads will let us. We expect to proceed slowly, starting with tunnels—yards—bridges, and the less important tracks, but we fully believe that our most optimistic views today will not be even a fraction of the real welding work the future holds.

INSTRUCTION MANUALS

Instruction manuals are available for arc, gas, resistance and thermit welding. These manuals cover fundamental information relative to these several processes of welding and are designed primarily to meet the needs of the student welder and engineer. Price per copy 50c. Lots of 100—$30.00. American Welding Society, 29 West 39th Street, New York, N. Y.

Code 1 Part A

Code for Fusion Welding and Gas Cutting in Building Construction

Formulated by
American Welding Society
Committee on Building Codes

Part A—Structural Steel
Edition of 1928

AMERICAN WELDING SOCIETY
33 West 39th Street
New York City

CONTENTS

Section	Subject	Page
1.	General Application	5
2.	Definitions	5
3.	Materials	6
4.	Permissible Unit Stresses	6
5.	Design	6
6.	Workmanship	7
7.	Erection	8
8.	Gas Cutting	8

For brevity the publication entitled "Specifications for Test Specimens, Their Preparation and Testing," dated July 18, 1928, prepared by the Structural Welding Committee of the American Bureau of Welding, is referred to herein as "American Bureau of Welding Specifications."

Copyright, 1929, by
American Welding Society
33 West 39th Street
New York City

PREFACE

The increase in the use of welding and gas cutting in the construction and equipment of buildings has brought to the American Welding Society a number of requests from municipal and other authorities for assistance in the formulation of regulations in the revision of existing Building Codes and the compilation of new codes where none is now in force, which will insure the safe and satisfactory use of the processes in the fabrication and erection of structural steel, piping and tankage in building construction.

In response to these requests a Committee on Building Codes was appointed by the President of the American Welding Society to undertake the codification of those practices in the application of fusion welding and gas cutting in building construction which have reached the stage where they may be properly standardized.

Recommended practices in the application of fusion welding and gas cutting to structural steel have been prepared by the Committee and formulated in the accompanying Part A "American Welding Society Code for Fusion Welding and Gas Cutting of Structural Steel," which part has been formally approved by the Society. This document has been so arranged that it may be embodied wholly or in part in existing municipal or other Building Codes. Care has been taken to be conservative in the formulation of this code. The various regulations are based on practices which have been demonstrated to be safe by experience, covering many full size destructive tests and numerous welded building structures erected throughout the country.

This being the first edition of the Code, it has been made as simple and as devoid of details as possible. The Committee is prepared, however, to assist in the interpretation of the Code or its applications. Communications should be addressed to the American Welding Society, 33 West Thirty-ninth Street, New York City. The Society reserves the privilege of publishing inquiries and answers in its Journal, with the name of the inquirer omitted.

Codes dealing with fusion welding and gas cutting, as applied, respectively, to piping and tankage in buildings, are being prepared and will appear as Parts B and C. Other codes will be undertaken as the need for them arises. It is the purpose of these codes to serve and assist all

interested in providing safe welded construction and to aid municipal and other authorities responsible for the preparation and enforcement of general building codes in the regulation of construction welding.

Following is the personnel of the Committee on Building Codes as at present constituted:

E. A. Doyle (Chairman)	The Linde Air Products Co.
J. L. Anderson	Air Reduction Sales Company.
Gilbert D. Fish	Westinghouse Electric & Manufacturing Co.
F. T. Llewellyn	U. S. Steel Corporation.
F. P. McKibben	General Electric Company.
H. H. Moss	The Linde Air Products Co.
James W. Owens	Newport News Shipbuilding & Dry Dock Co.
Edmund Vom Steeg	General Electric Company.

The Committee is authorized at all times to call for advice and assistance from responsible members of National Technical and Regulatory bodies in the work of preparing Welding Codes and the Committee proposes to enlist such aid as the needs arise.

F. T. LLEWELLYN, *President.*
American Welding Society.

Code for Fusion Welding and Gas Cutting in Building Construction

Part A—Structural Steel

SECTION 1. GENERAL APPLICATION

1. Fusion welding may be substituted for or used in combination with the riveting, bolting or other requirements already prescribed in the building code of the City of ————————, hereinafter called the "Building Code", for connecting together, or assembling the component parts of, steel beams, girders, lintels, trusses, columns and other structural steel used in building construction; provided that the welding be done in accordance with Sections 3 to 7, inclusive, of this code.

2. Gas cutting may be substituted for shearing or sawing in the fabrication of structural steel members or parts, used in building construction, provided the cutting be done in accordance with Section 8 of this code.

SECTION 2. DEFINITIONS

The definitions of welding terms, as approved and published by the American Welding Society, shall govern for any welding terms appearing in this code.

For convenience, some of the more common terms have been included herein, and their specific applications under this code are defined as follows:

1. *Fusion Welding*—The process of joining metal parts in the molten, or molten and vapor states, without the application of mechanical pressure or blows.

Under this code, fusion welding is restricted to the arc and gas welding processes.

2. *Root*—The zone at the bottom of the cross-sectional space provided to contain a fusion weld.

3. *Throat*—The minimum thickness of a weld along a straight line passing through the root.

Under this code the throat of a fillet weld shall be the distance along a line from the root to the hypotenuse at right angles thereto, of the largest isosceles right triangle that can be constructed in the cross-section of the fillet weld; and the throat of a butt weld shall be equal to the thickness of the thinner part joined.

4. *Fillet Weld*—A weld of approximately triangular cross-section, whose throat lies in a plane disposed approximately 45 degrees with respect to the surfaces of the parts joined.

The *size of a fillet weld* shall be expressed in terms of the width in inches of its adjacent fused sides.

5. *Butt Weld*—A weld whose throat lies in a plane disposed approximately 90 degrees with respect to the surfaces of at least one of the parts joined.

The *size of a butt weld* shall be expressed in terms of its net or unreinforced throat dimension in inches.

6. *Weld Length*—The length of a weld shall be considered to be the unbroken length of the full cross-section of the weld exclusive of the length of any craters.

7. *Weld Dimensions*—Under this code the dimensions of a weld shall be expressed in terms of its size and length.

8. *Gas Cutting*—The process of severing ferrous metals by means of the chemical behavior of oxygen, in the presence of ferrous metals at high temperatures, to produce a kerf or cut of uniform width without burning the edges of the kerf or cut.

SECTION 3. MATERIALS

1. The grade of structural steel to be used under this code shall be that already prescribed in the Building Code.

2. The electrodes, welding wire and/or welding rods, shall either be one of the grades specified by the American Bureau of Welding in its Bulletin Number 2, or some equally good grade which, in the hands of an experienced welder, shows good weldability in flat, vertical and overhead positions. In the discretion of the Superintendent of Buildings it may be required to show the strength specified in Paragraphs c and g, Section B, of the American Bureau of Welding Specifications.

SECTION 4. PERMISSIBLE UNIT STRESSES

1. Welded joints shall be proportioned so that the loads specified in the Building Code shall not cause stresses therein to exceed the following amounts in pounds per square inch:

Shear on section through throat of weld	11,300
Tension on section through throat of weld	13,000
Compression on section through throat of weld	15,000

Maximum fiber stresses due to bending shall not exceed the values prescribed above for tension and compression respectively.

2. In designing welded joints adequate provision shall be made for bending stresses due to eccentricity, if any, in the disposition or section of base metal parts.

SECTION 5. DESIGN

1. The architect or engineer designing or supervising a welded structure shall be experienced and skilled in such work.

2. *Plate Girders*—Girders shall be proportioned either by their moments of inertia or by the flange area method. In applying the flange area method to welded girders having no holes in the web, one-sixth of the web area may be considered a part of each flange area.

Stiffeners may be either angles or flat bars, welded to the top and bottom flanges, and to the web, by continuous or intermittent fillet welds designed to transmit the stresses.

Connection of component parts of flanges to each other and of flanges to web shall be by continuous or intermittent fillet welds designed to transmit the stress.

3. *Beams*—The use of continuous beams and girders, designed in accordance with accepted engineering principles, shall be permitted provided that their welded connections be designed to transmit the stresses to which they may be subjected.

The connections at the ends of non-continuous beams shall be designed so as to avoid excessive secondary stresses due to bending.

4. *Columns*—Fillet welds connecting the component parts of a built-up column may be either continuous or intermittent. If intermittent, the length of each weld at the ends of the column shall be equal to the least width of the column. The length of the intervening welds shall be not less than 1½ inches, spaced not more than 4 inches in the clear. The size, length and spacing of the fillet welds shall be such as to provide the same strength, per unit of column length, as the rivets specified elsewhere in the Building Code.

Lattice bars and tie plates, if used, shall be welded so as to secure strengths equal to those of the rivets specified therefor elsewhere in the Building Code.

5. *Butt Joints*—The edges of base metal parts, ¼ inches or more in thickness, transmitting stress by means of butt welds shall be beveled. For single and double vee joints, the bevel of each part shall be not less than 30 deg., thus forming an open space with an angle of not less than 60 deg. For single and double bevel joints, the bevel shall be not less than 45 deg.

Before welding, the root edge or face of one part shall be separated from the root edge or face of the other part by the spacing given for butt joints on pages 22 to 28 inclusive, of Section E of American Bureau of Welding Specifications.

All butt welds shall be reinforced by depositing additional metal on the weld to a height extending beyond the surface of the thinnest part joined. The height of said reinforcement shall be not less than the following percentages of the thickness of the thinnest part joined:—20 per cent for single vee and single bevel butt welds, and 12½ per cent, on each side, for double vee and double bevel butt welds.

SECTION 6. WORKMANSHIP

1. Contractors for welded structures shall be required to satisfy the Superintendent of Buildings as to their ability to produce satisfactory

welded joints of the forms specified, and with the process (arc or gas), materials and equipment to be used on the proposed work.

2. The quality of welds permitted under this code shall conform to the practice recommended in Section D of the American Bureau of Welding Specifications.

3. Surfaces to be welded shall be free from loose mill scale, rust, paint or other foreign matter. A thin coat of linseed oil or equivalent, over the surfaces to be welded, need not be removed. This provision applies both in the case of new structures and where new steel is to be welded to steel in an existing structure.

4. In assembling and during welding, the component parts of a built-up member shall be held by sufficient clamps, or other adequate means, to hold the parts in proper relation for welding.

SECTION 7. ERECTION

1. Structural steel parts shall not be painted before they are welded. Parts that are welded in the shop, to be erected by bolts or rivets, shall receive the usual painting after the shop welding is finished. Parts to be field welded shall receive a coat of linseed oil after shop work is completed, and after erection and field welding, they shall receive as many coats of paint as the total number specified elsewhere in the Building Code for shop and field painting.

2. For all welded structures over 30 ft. in height, erection bolts, or equivalent means shall be employed for temporarily supporting the members and for insuring proper alignment.

SECTION 8. GAS CUTTING

1. The contractor shall be required to satisfy the Superintendent of Buildings as to his ability to produce satisfactory gas cuts.

2. Gas cut edges shall be smooth and regular in contour.

3. Gas cutting may be used in the preparation of base metal parts for welding, provided the edges so cut are thoroughly cleaned after cutting so as to expose clean steel.

4. Gas cutting shall not be permitted to replace the milling of surfaces specified elsewhere in the Building Code.

5. Gas cutting shall not be permitted on any member while it is carrying stress. This restriction shall not apply to detail cutting for the correction of minor fabricating errors, where the removal of metal resulting from such gas cutting would not reduce the required strength of the member that is to be cut.

6. Gas cutting of holes in a member which has not been designed therefor shall not be permitted.

Organizing and Operating an Industrial Welding School*

R. B. LINCOLN†

PROBABLY there are as many different ways of conducting a welding school as there are schools. The methods best suited to one locality and industry may not be the best suited to another but by interchanging ideas we can all profit. Even when it is not possible to adopt a method 100 per cent, certain features may be adapted to the work at hand.

I will describe the methods used in organizing and operating the welding school at the Westinghouse Electric and Manufacturing Company and show a few slides which will illustrate the school better than words.

The Welding School at East Pittsburgh Works of the Westinghouse Electric & Manufacturing Company was started about 12 years ago and developed with the welding industry. In the early days welding was used largely as a repair tool, and the slow development at that time did not call for a large supply of trained welders. During the war, the high price of high speed tool steel resulted in arc welding being pressed into service to weld bits to soft steel shanks. There were other means of doing this operation, of course, but partly due to the fact that arc welding seemed the best adapted at the time for the particular work, and partly because other equipment was very busy arc welding was the favorite means of attaching high-speed steel bits, for a time.

The general need of economy, intensive production, and the salvaging of waste products resulted in further employment of welding. These developments demanded a supply of trained welders, not only for our own shops but for the country in general and resulted in the establishment of our welding school. After the war, a part of the facilities of the welding school was devoted to the rehabilitating of returned soldiers, in cooperation with the Government.

Each succeeding year saw increased use of welding and increased demand for trained men. The school grew in size and developed in technique to its present status, and we believe we have today a very thorough course in training. It is more than just a school for beginners. It is a center around which much of our shop development revolves. It is closely connected with our staff activities in welding and assists in upholding a high standard of workmanship in welding, as will be pointed out later.

In addition to the Day School, there are two evening classes, each meeting two evenings a week which are open to the public as well as to Westinghouse employees. A tuition of $20.00 is charged for 72 hours training in the Night School.

*Paper presented at Annual Meeting, A. W. S., April 24, 1929.
†Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.

At the Sharon Plant Works of the Westinghouse Electric & Manufacturing Company, another welding school is located. It is a little smaller in size than the East Pittsburgh school but is operated day and night (full turns).

These two schools train the personnel for shops employing over three hundred welders, besides training many men for other companies and certain of our own designers and supervisors that require a knowledge of welding to perform their work.

FIG. 1—INTERIOR OF WELDING BOOTH IN SCHOOL

Generally the students fall within one of three classes. First: Employees of customers wishing to learn to weld or to secure additional training in this work. Second: Prospective operators for our own welding operations. Third: Members of our engineering, inspection or supervisory forces who require training in welding to better design, inspect, and control the work. Naturally, conditions differ in the three classes in some points but the training is much the same.

In the first case cited, i.e., men sent here by customers, the selection

of the men is entirely up to the company sending them to the school, and the time spent at the school is also determined by the same authority but frequently the advice of our welding engineers is sought and followed.

In the case of prospective operators for our own shop, the greatest care is used in the selection of the students to be trained, and they are kept in the school until they arrive at a definite standard of skill, usually about 4 or 5 weeks. When they leave the school, another instructor takes them in charge and supervises their work closely for a period of two months. During this time, they are assigned to the simpler jobs of welding. After this period, they are assigned to more difficult jobs, and are given special instruction from time to time as conditions require.

FIG. 2—HAND MACHINE USED IN BREAKING WELDS MADE BY STUDENTS

After a period of one to three years, the welder will have acquired skill to make any kind of a weld called for in his line of work.

The students for the regular day school are selected from workmen, in the shop and paid full time while learning. No tuition is charged. In doing this, we are investing a considerable sum in the man's training, but under present conditions, this seems to be the best thing to do. It permits the selection of the very best material for the classes. The men are selected for general mechanical experience, and high order of intelligence which aids in shortening the training period and produces workmen of superior skill. At the same time, it serves as a reward for faithful services. If we selected from the unemployed, we would have

to be content with a lower standard of men, and there would be greater uncertainty about their background. If we undertook to select from old employees but required them to take the training at reduced pay, some of the men who make our best material for this training would be unable to finance themselves, no matter how much they wished to become welders.

At some future date if welding should reach a point of saturation and new operators would be required only to replace those retiring from the trade, this plan might not be the wisest course. At present, it seems to work very well.

A candidate for the training is selected by a Superintendent or a General Foreman, interviewed and approved by the Assistant Superintendent of Trades Training and the Supervisor of Welding. If at any point during his training, it develops that a mistake has been made, the Superintendent is consulted and the workman returned to his old job. However, the triple selection referred to usually results in a satisfactory choice of men.

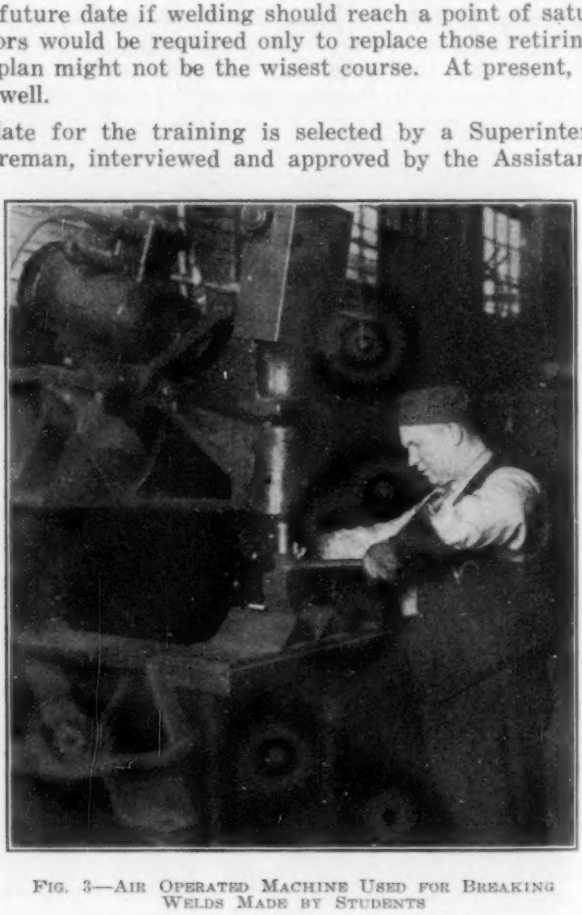


FIG. 3—AIR OPERATED MACHINE USED FOR BREAKING WELDS MADE BY STUDENTS

Upon starting in the school, the prospective welder is given a manual, especially prepared for the school. The apparatus and processes are then explained to him by the instructor. His first task consists of cutting a plate of steel about one-half inch thick with a carbon arc. This is

chosen because it is believed to be the simplest operation requiring the holding of an arc. When he has mastered this, he is given a metallic electrode and taught to lay a straight bead on a steel plate. Later he joins plates with the various types of welds and they are broken apart to discover the imperfections, if any, in the weld. In the latter part of his stay in the school, he is taught vertical, overhead, and oil-tight welding.

From time to time the students are gathered into the main room of the school and given a talk on some particular phase of their work but the greater part of their training is in the welding booth, holding an arc.

Special attention is given during the talks to the expansion and contraction of metals. The student is taught to think out for himself the cause, when these forces disturb his work.

The skill and integrity of the workman is one of the best guarantees of quality of welding, as in most other lines of work. After selecting and training the man with care, we do not allow him to "back-slide" when he completes the school work. Once a month each welder throughout his entire period of employment is required to weld certain test specimens which are sent to the physical laboratory and he is graded accordingly. The Supervisor of Welding serves as a sort of super-instructor to correct any bad habits that a workman may acquire and to see that the standard procedure is followed.

Each welder is given a stencil and required to mark his work. We call this signing his work although a symbol is used in place of his name. We believe that this is of a great value in holding up quality as it gives the man a feeling of responsibility, and pride in his work.

To get the best results from welding, the designs should be adapted to welding. This requires a designer who has some knowledge of the technique. Many of our engineers have donned overalls and taken the course. In this case, the practice periods are somewhat shortened partly due to their better ability to learn and partly because they do not require the same degree of manual skill as a shop man. They usually complete the course in two weeks and after this training, I believe, are much better able to utilize in full, this new method of fabricating machines.

Some of our inspectors are skilled welders and all of those who come in contact with welding have been given the welding school training.

Thus we train not only the operator but the designer and inspector. The shop and engineering departments cooperate to perfect both workmanship and design.

In starting a new school, I believe that the selection of the instructor is of utmost importance. He should be a first class welder of wide experience. He should have patience and understand how to communicate his knowledge to others. The welding instructor may be called upon to advise the design department, in which case, he should have some knowledge of stress and the strength of materials, or at least be a type of man who will study and acquire such knowledge, in case his work requires it.

The equipment of the school should be of the same type as used in the shop or field so as to reduce to a minimum, the difficulty of the student adapting himself to new conditions.

The training should follow a well thought out plan and each lesson should be practiced until the work can be done in a satisfactory manner.

CURRENT WELDING LITERATURE

A Test on Metallic Arc-Welded Flanges, Bends and Tees of a Six-Inch Steam Main. H. E. Grove. Mechanical and Welding Engineer (March 20, 1929), Vol. 3, No. 3, pp. 88-89.

Airplane Welding Fixtures. American Machinist (April 4, 1929), Vol. 70, No. 14, p. 542.

Arc Welding of Steel Buildings and Bridges. F. P. McKibben. Engineering and Contracting (May, 1929), Vol. 48, No. 5, pp. 209-212. An up-to-date résumé of the situation.

Competition for Practical Welders. Mechanical and Welding Engineer (March 20, 1929), Vol. 3, No. 3, pp. 77-80. Boiler repairs. Welding cast iron. Tank welding outback. Boiler shops—Welding versus riveting.

Electric Arc Welding. Edward Dacre Lacy. Mechanical and Welding Engineer (March 20, 1929), Vol. 3, No. 3, pp. 99-101. An efficient method of ship-repairing and construction.

Experience in the Use of Welded Joints in Lieu of Lead for Steel Pipes. H. M. Trethowan. Mechanical and Welding Engineer (March 20, 1929), Vol. 3, No. 3, pp. 90-91.

Micro Structure of Electric Arc Welds in Structural Steel. H. L. Publow and F. L. Reynolds. Michigan Engineering Exp. Sta. Bulletin No. 21 (January, 1929).

Oxy-Acetylene Welding and Cutting. W. D. Sear, Mechanical and Welding Engineer (March 20, 1929), Vol. 3, No. 3, pp. 84-85. System should be understood by operators.

Oxy-Acetylene Welding in the Foundry. G. F. Wieser. Mechanical and Welding Engineer (March 20, 1929), Vol. 3, No. 3, pp. 102-104. The welding torch is an important factor in assisting the up-to-date foundryman to keep costs down, to make deliveries of sound, well-finished castings when promised.

Precision Weld Testing. J. B. Green. The Welding Engineer (April, 1929), Vol. 14, No. 4, pp. 35-37. Methods of determining physical properties of welds under conditions met in practice and expressing the results in recognized units.

Program of the Joint Research Committee on Welding of Pressure Vessels. Mechanical Engineering (April, 1929), Vol. 51, No. 4. p. 282.

Revisions and Addenda to the Boiler Construction Code. Mechanical Engineering (April, 1929), Vol. 51, No. 4, pp. 315-319.

Silver Brazing and Soldering in Airplane Construction. R. R. Shuman. Mechanical and Welding Engineer (March 20, 1929), Vol. 3, No. 3, p. 105.

Steel Frame Fabricated in the Field. The Iron Age (April 18, 1929), Vol. 123, No. 16, p. 1067.

Steel Pipe Line Welded Above Ditch, Then Lowered. Engineering and Contracting (May, 1929), Vol. 48, No. 5, p. 200.

Supervision in Welding. J. Lyall. Mechanical and Welding Engineer (March 20, 1929), Vol. 3, No. 3, pp. 82-83. Expansion and contraction of sheet metal.

The Acid Test of Quality Selling. J. D. Tierney. The Welding Engineer (April, 1929), Vol. 14, No. 4, pp. 39-41. Welding contractor sells 70,000 extra feet of welding on tanks by actually trying what was said to be impossible.

The Art of Fusion Welding. J. W. Morris. Mechanical and Welding Engineer (March 20, 1929), Vol, 3, No. 3, p. 86.

The Construction and Protection of Oil and Natural-Gas Pipe Lines. W. H. T. Thornhill. Pipe Line News (April, 1929), Vol. 1, No. 5, pp. 5-13. Magnitude

of pipe line transportation systems. Methods used in field construction. Welding joints in pipe lines. Ditching and lowering of pipe into ditch. Laying all-coupled lines. Protection of lines against soil corrosion. Requirements of a good protective coating.

Theoretical and Experimental Researches on Electric Resistance Welding. Takesi Okamoto. Reprinted from the Memoirs of the College of Engineering Kyoto Imperial University. Vol. VI, No. 1, 1929. Theoretical investigations. Experimental investigations of percussion welding. Distribution and change of temperature in butt welding. Change in the metallographical structure and hardness. Experimental research on butt welding of soft steel bars. Relations between the welding time, power and energy consumption. Effect of various welding conditions on the tensile strength of welds. Butt welding of copper bars. Butt welding of brass wire.

Welded Oil Line in the Caucasus. A. A. Heller. The Welding Engineer (April, 1929), Vol. 14, No. 4, pp. 51-52. American firm takes hand in the construction of a 570-mile pipe line from Baker oil wells to the Black Sea.

Welders Discuss Chemical Equipment. The Iron Age (May 2, 1929), Vol. 123, No. 18, pp. 1217 and 1258. Proper procedure for welding nickel outlined. Data on steel vessels for high temperature and pressure.

Welding a Four-Story Commercial Building. Engineering News-Record (April 18, 1929), Vol. 102, No. 16, pp. 618-621. Design and erection utilize possibilities of welding.

Welding Experiences Abroad. Mechanical and Welding Engineer (March 20, 1929), Vol. 3, No. 3, pp. 92-95.

Welding Practice in the Aircraft Industry. J. F. Hardecker and E. A. Joyce. The Welding Engineer (April, 1929), Vol. 14, No. 4, pp. 43-45. Selection of equipment. Materials. Requirements of the weld. Procedure control. Duties of the supervisor.

Welding Service Onto Plow Shares. The Welding Engineer (April, 1929), Vol. 14, No. 4, pp. 53-55. Tests show that standard steel plow shares which have been steilited will stay in the ground 5½ times as long and remain sharp.

Welded Stainless Steel. Mechanical and Welding Engineer (Feb. 20, 1929), Vol. 3, No. 2, p. 42.

Welded Structural Steel Bed-Plate Tested. The Iron Age (March 28, 1929), Vol. 123, No. 13, p. 898.

Welding—A New Tool for the Structural Fabricator. F. T. Llewellyn. Engineering News-Record (March 21, 1929), Vol. 102, No. 12, pp. 459-462. Present state of the art, particularly the arc process, as it has been developed over the past two and a half years.

Welding Applied to Shipbuilding. J. W. Owens. Marine Engineering (February, 1929), Vol. 34, pp. 100-1. Illustrates fundamental forms of fillet and fusion welds.

Welding and Cutting Practice with Low Pressure Plant. C. S. Milne. The Welding Journal (March, 1929), Vol. 26, No. 306, pp. 74-79.

Welding Characteristics of Copper Alloys. Wire and Wire Products (April, 1929), Vol. 4, No. 4, pp. 122 and 138. Widely varying compositions of brass and bronze are weldable when proper precautions are taken.

Welding Copper, Brass and Bronze. Ira T. Hook. The Welding Engineer (March, 1929), Vol. 14, No. 3, pp. 45-48. Welding characteristics and strength of alloys of copper, tin and zinc in various proportions, and procedure for successful welding by torch or metallic arc.

Welding Facts and Figures—34. D. Richardson and E. W. Birch. The Welding Journal (February, 1929), Vol. 26, No. 305, pp. 38-40. Stainless steels and irons. Physical properties of stainless iron.

Welding Facts and Figures—35. D. Richardson and E. W. Birch. The Welding Journal (March, 1929), Vol. 26, No. 306, pp. 70-73. Handbook for welding engineers. Analysis of typical acid and heat-resisting alloys.

Welding on Buildings. Mechanical and Welding Engineer (Feb. 20, 1929), Vol. 3, No. 2, p. 62. Detroit architect speeds erection with welding and cutting equipment.

YOU CAN DO IT BETTER WITH TORCHWELD

Torchweld patented safety features are positive and protect your operators.

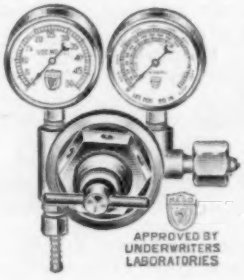
Torchweld Equipment cuts labor and gas costs, also upkeep expense.

This same safety and dependable service are available to you.

Write for Catalog No. 28

TORCHWELD EQUIPMENT COMPANY

224 N. Carpenter St. Chicago, Illinois



If You Want to Know Why

REGO

OXY-ACETYLENE EQUIPMENT

Gives more satisfactory service. Operates with a lower gas cost. Costs less to maintain *than any other equipment—*

Write for Booklet - "FACTS"

THE BASTIAN-BLESSING CO.

252 E. Ontario St. Chicago

Since 1911, *Meco* Oxy-Acetylene continues to improve and show greater efficiency. Exclusive features invariably mean standardizing on *Meco* after the first trial.

Multi-Seat Regulators deserve your immediate investigation. Write now.

MODERN ENGINEERING COMPANY

3411-13 Pine Blvd. St. Louis, Mo.

Vision Protecton With ESSENTIALITE

glare proof welding glass

Made from a special glass that FILTERS the GLARE, producing a softer and more comfortable vision.

ESSENTIALITE LENSES ARE SCIENTIFICALLY CORRECT, for Electric Welding there are none better—they positively aid in conserving the eyesight of those who are subjected to welding glare.

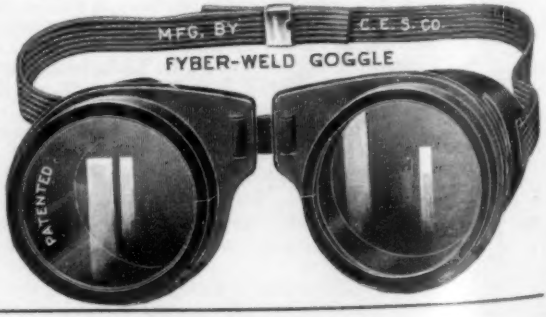
Manufactured by

CHICAGO EYE SHIELD COMPANY

2300 Warren Ave. Chicago, Ill.

We make a full line for the face and head protection of the Welder.

Hand Shields, Helmets
Sand Blast Helmets
Goggles and Glass



Our Advertisers Are Supporting the Society.